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ARMY ENGINEER DISTRICT, PHILADELPHIA PA
FLOOD PLAIN INFORMATION, MILL CREEK, NEW CASTLE COUNTY, DELAWARE--ETC(U)
MAY 73

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MILL CREEK NEW CASTLE COUNTY
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FLOOD PLAIN INFORMATION

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MILL CREEK
NEW CASTLE COUNTY
DELAWARE

LEVEL II

OTIC



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MAY 1973

DAEN/NAP-82040/FPI 26-73/05

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FLOODS
ON
MILL CREEK
NEW CASTLE
COUNTY DEL.



ACTION is needed

The flood plain of Mill Creek is sparsely developed but expansion and redevelopment of residential and commercial properties can be expected in the future. The devastating effects of flooding will continue to increase unless action is taken.

Effective regulatory measures such as zoning ordinances and building codes can be designed to prevent increased flood damages. Flood proofing can reduce potential damages to properties already subject to flooding, and additional works to modify flooding can also be a part of the long-run solution.

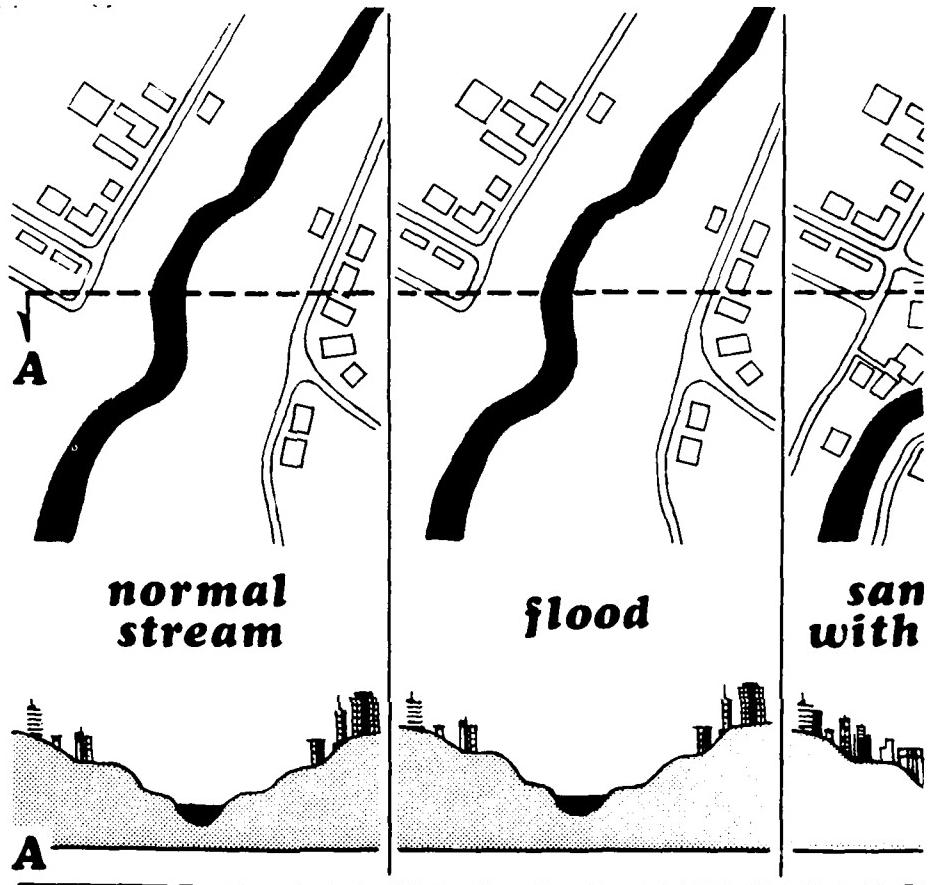
The communities along Mill Creek are not the only communities with flooding problems. Flood plain information has already been provided for many of several thousand flood-plagued communities. Nearly 600 of those having FPI Reports by mid 1972 have adopted or strengthened regulations, while 760 others have them under study. A total of 1,370 communities have used the FPI Reports in planning land use control.

This folder has been prepared for the New Castle County Department of Planning by the U.S. Army Corps of Engineers from data in the report "Flood Plain Information, Mill Creek, New Castle County, Delaware."

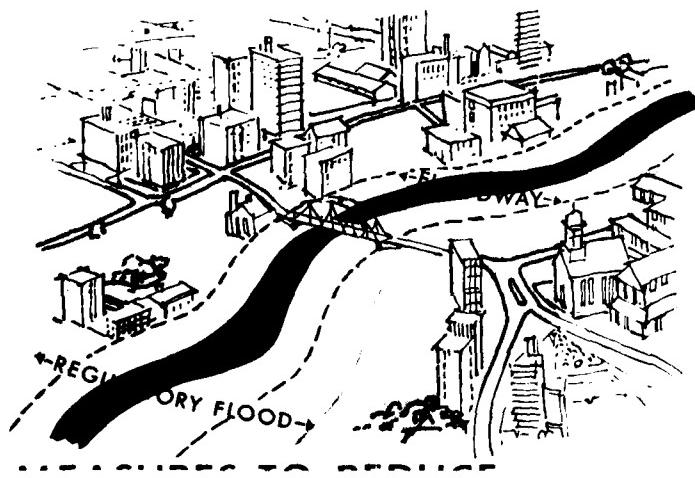
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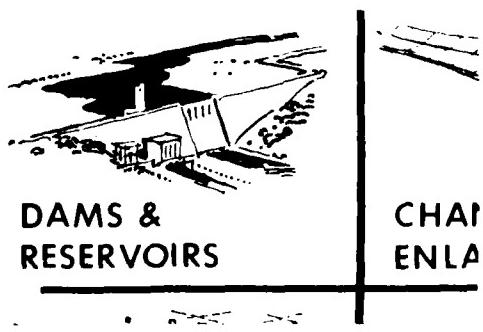
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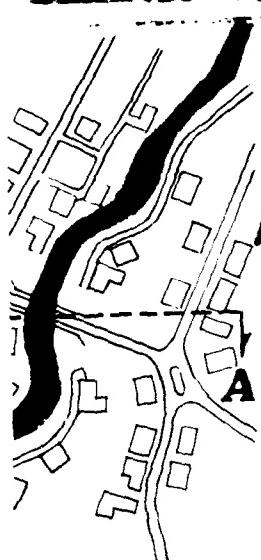


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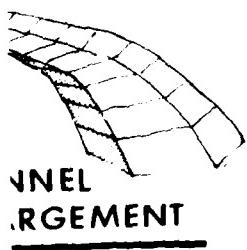
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**OTHER
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EDUCATION

**TAX
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MEASURES TO REDUCE VULNERABILITY

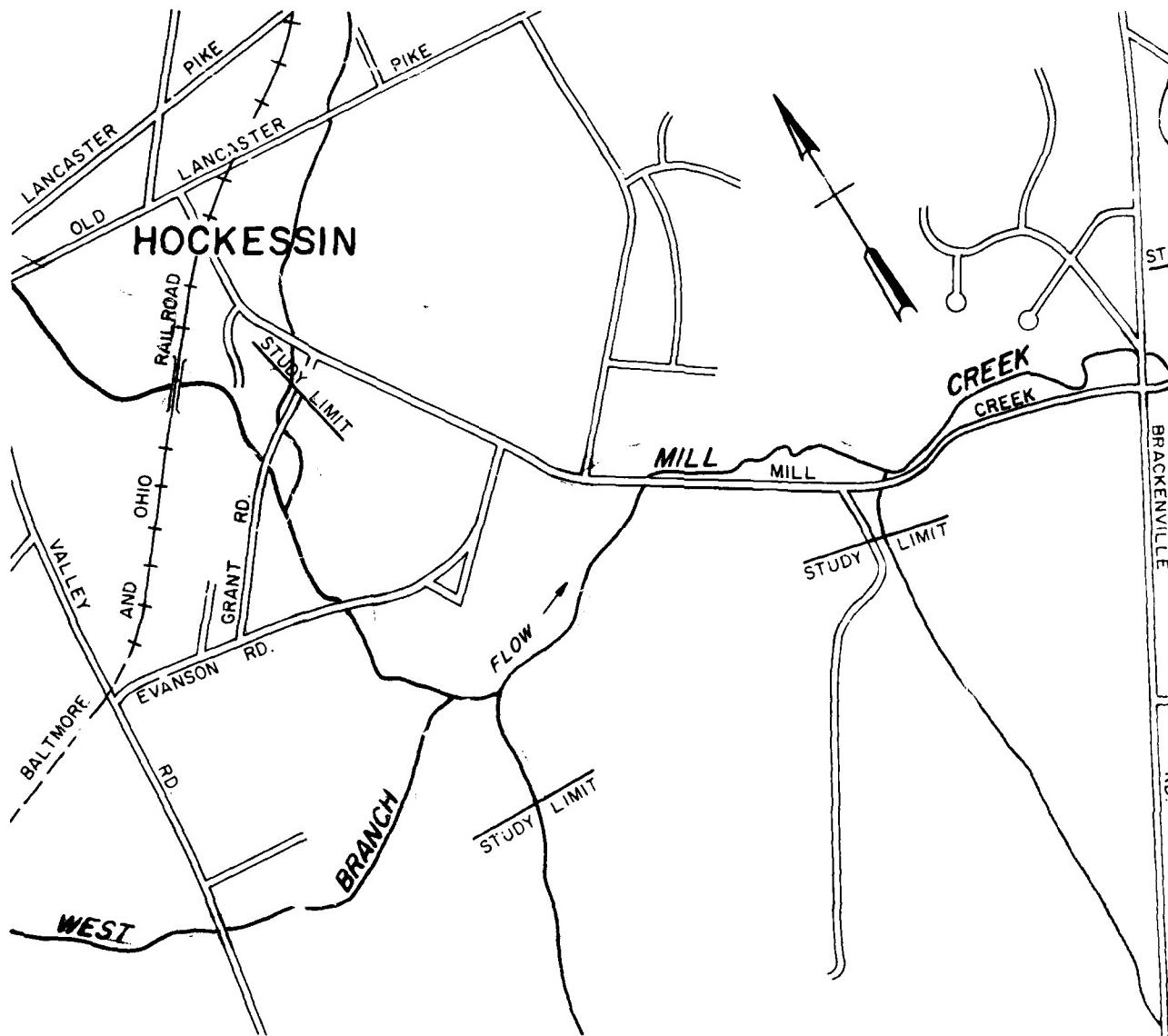
TO FLOODS provide for a future with more freedom from flood damage, often at minor cost and with little adverse effect on the environment

REGULATIONS

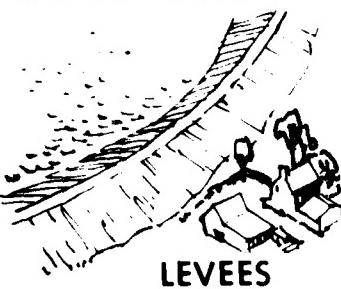
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- FLOOD PROOFING • RELOCATIONS •
- URBAN RENEWAL •

HIGH FLOW DIVERSION



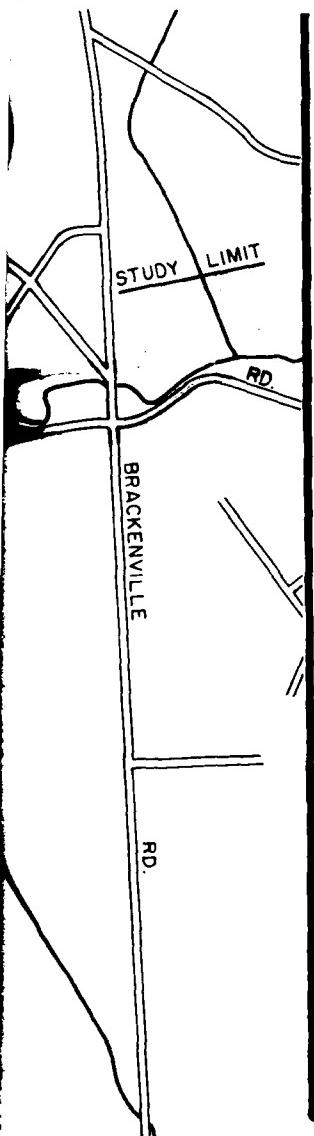
ENLARGEMENT



ADJUSTMENTS

FLOOD
INSURANCE

WARNING &
EMERGENCY
PLANS



FLOOD PATTERNS

for

MILL CREEK

LEGEND

approximate limits
of overflow

■ NORMAL STREAM

INTERMEDIATE
REGIONAL FLOOD (IRF)

STANDARD PROJECT
FLOOD (SPF)

PROFILES in the
Flood Plain Information Report
show elevations of
these floods
for the entire study area

TO THE REQUESTOR:

This Flood Plain Information (FPI) Report was prepared by the Philadelphia District office of the U.S. Army Corps of Engineers, under the continuing authority of the 1960 Flood Control Act, as amended. The report contains valuable background information, discussion of flood characteristics and historical flood data for the study area. The report also presents through tables, profiles, maps and text, the results of engineering studies to determine the possible magnitude and extent of future floods, because knowledge of flood potential and flood hazards is important in land use planning and for management decisions concerning floodplain utilization. These projections of possible flood events and their frequency of occurrence were based on conditions in the study area at the time the report was prepared.

Since the publication of this FPI Report, other engineering studies or reports may have been published for the area. Among these are Flood Insurance Studies prepared by the Federal Insurance Administration of the Federal Emergency Management Agency. Flood Insurance Studies generally provide different types of flood hazard data (including information pertinent to setting flood insurance rates) and different types of floodplain mapping for regulatory purposes and in some cases provide updated technical data based on recent flood events or changes in the study area that may have occurred since the publication of this report.

It is strongly suggested that, where available, Flood Insurance Studies and other sources of flood hazard data be sought out for the additional, and, in some cases, updated flood plain information which they might provide. Should you have any questions concerning the preparation of, or data contained in this FPI Report, please contact:

U.S. Army Corps of Engineers
Philadelphia District
Custom House, 2nd and Chestnut Streets
Philadelphia, PA 19106

ATTN: Flood Plain Mgt. Services Branch, NAPEN-M

Telephone number: (215) 597-4807

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report covered the flood situation along Mill Creek from its confluence with the White Clay Creek near the Delaware Park Race Track to its headquarters north of Hockessin, Delaware near the Pennsylvania-Delaware State Boundary. It included a history of flooding along Mill Creek, Del. and Identified areas which may be subject to possible future floods. Special emphasis is given to future floods thru maps, photographs, profiles and cross sections.		

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Under authority of Section 206 of the 1960 Flood Control Act as amended the flood plain information was prepared by the U.S. Army Corps of Engineers Philadelphia District at the request of the New Castle County Department of Planning. The information should be considered for its historical nature. Since the publication of this FPI report other Flood Insurance studies have been undertaken and should also be consulted for more current information.

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

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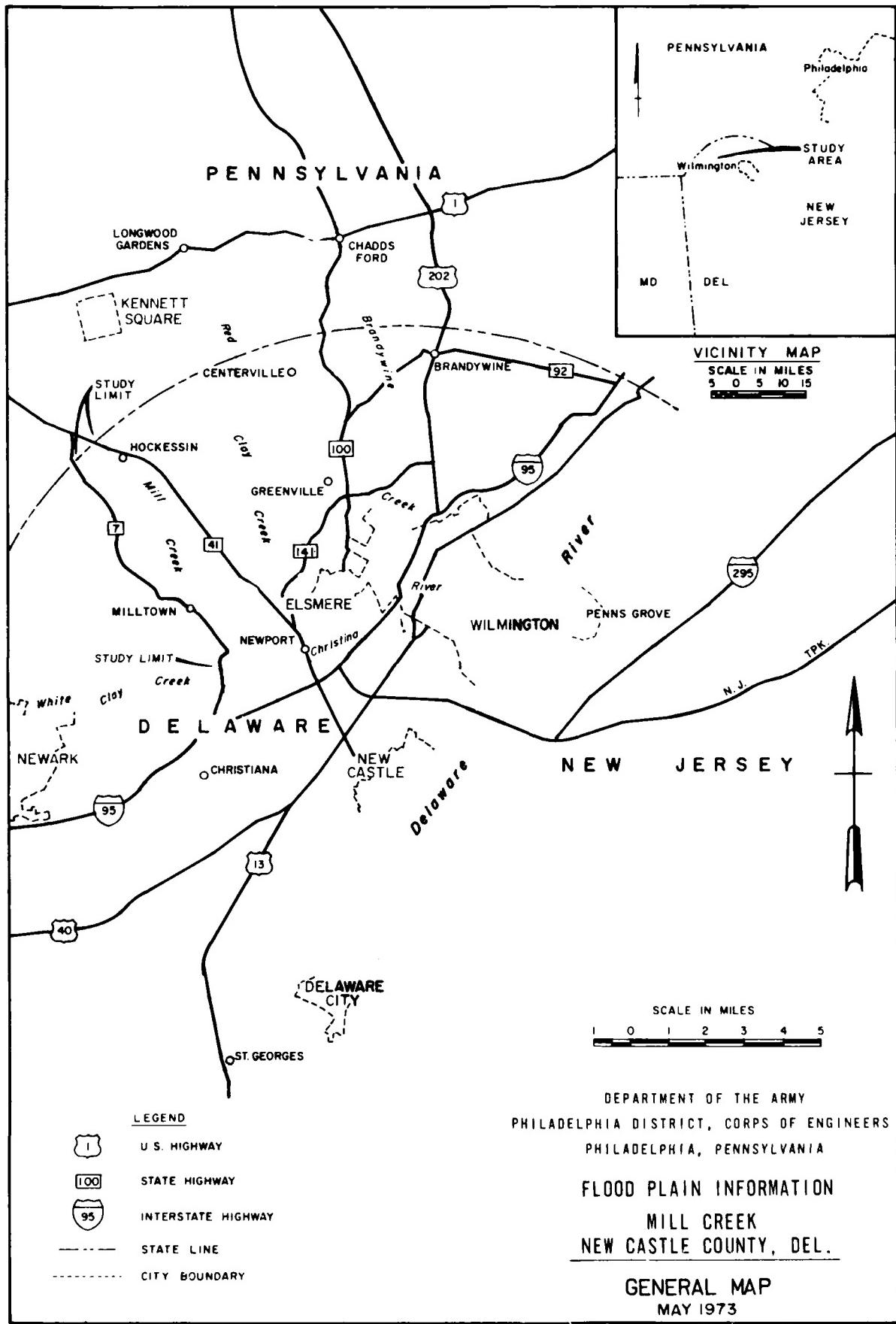


PLATE I

PREFACE

This report covers the flood situation along Mill Creek from its confluence with the White Clay Creek near the Delaware Park Race Track to its headwaters north of Hockessin, Delaware, near the Pennsylvania-Delaware State Boundary. The properties located on the flood plain along Mill Creek are primarily residential and commercial and have been damaged by past floods. Many areas along Mill Creek may become more populated and developed in the future. Although large floods have occurred in the past, studies indicate that even larger floods are possible.

This report has been prepared because a knowledge of flood potential and flood hazards is important in land use planning and for management decisions concerning flood plain utilization. It includes a history of flooding along Mill Creek and identifies those areas that are subject to possible future floods. Special emphasis is given to the possible future floods through maps, photographs, profiles and cross sections. The report does not provide solutions to flood problems; however, it does furnish a suitable basis for the adoption of land use controls to guide flood plain development and thereby prevent intensification of the flood loss problems. It was also aid in the identification of other flood damage reduction techniques such as works to modify flooding and adjustments including flood proofing which might be embodied in an overall flood plain management (FPM) program. Other FPM program studies — those of environmental attributes and the current and future land use role of the flood plain as part of its surroundings — would also profit from this information.

At the request of the New Castle County Department of Planning this report was prepared by the Philadelphia District Office of the United States Army Corps of Engineers under the continuing authority provided in Section 206 of the 1960 Flood Control Act, as amended.

The assistance and cooperation of the United States Geological Survey (U.S.G.S.), the Soil Conservation Service, the New Castle County Engineering Department and the Department of Planning, and the Delaware State Department of Highways, in supplying useful data and photographs is appreciated.

Additional copies of this report can be obtained from the New Castle County Department of Planning. The Philadelphia District Office, upon request, will provide technical assistance to planning agencies in the interpretation and use of the data presented as well as planning guidance and further assistance, including the development of additional technical information.

BACKGROUND INFORMATION

Settlement

The early history of this watershed reflects the beginning history of Wilmington and Newport, Delaware. As such, much of the watershed has shared in the historical background of Swedish, Dutch and finally English conquests. In 1700 William Penn received title to land in the New World as payment for a debt owed to his father by King Charles II of England. Among Penn's holdings was land including much of the Mill Creek watershed. He granted this portion of his holdings to his younger children, and the land was developed agriculturally. Before the Industrial Revolution, many water-powered mills were operating along Mill Creek, grinding agricultural products and spinning textiles. Improved roads such as the Newport-Gap and Lancaster Turnpikes increased the market for local agricultural products by providing access to the major trading and shipping towns of Wilmington and Newport. Early towns such as Milltown and Hockessin developed around these mills. Hockessin also supported additional industries such as clay quarries, iron works, and mushroom houses.

The towns thrived until the beginning of the nineteenth century when a business depression occurred which forced the financial collapse of many mills and the abandonment of many mill towns in northern Delaware. The Chesapeake and Delaware Canal contributed to this business depression by de-emphasizing the usage of the Christina River as a trade route which had linked the watershed area to the urban markets of northern Delaware and southeastern Pennsylvania. The situation worsened as the agricultural heartland of central Pennsylvania began to compete in the urban markets with the northern Delaware agricultural industry by the shipment of goods through the canal. The ensuing depression brought financial collapse to those mills that did not diversify as had several mills in the Brandywine watershed.

Four years after race track betting was legalized in 1933, the completion of the Delaware Park Race Track introduced large scale commercial development in the southern portion of the watershed. This development which has acted as a core for smaller, related commercial enterprises, coupled with the expanding suburbs of Newark and Wilmington, has enhanced the possibilities of ever increasing development of the watershed.

The Stream and Its Valley

The main stem of Mill Creek extends 9.3 miles from its headwaters above Hockessin, Delaware, to its confluence with White Clay Creek near the Delaware Park Race Track. A tributary to Mill Creek referred to as the West Branch Mill Creek in this report is 1.4 miles in length and meets the main stem approximately five hundred feet downstream of Evanson Road near Hockessin. Traveling in a southerly direction, the main stem of Mill Creek runs parallel with Red Clay and Pike Creeks. Another fairly large, unnamed tributary flows into the main stem approximately one mile above Mill Creek's confluence with White Clay Creek. At its confluence with White Clay Creek, Mill Creek drains 12.7 square miles of agricultural land, small wood lots, grassland and residential land. In the northern part of the watershed, above the confluence with the West Branch, the stream gradient averages 55 feet per mile. The middle portion of the watershed from the confluence of West Branch to the Limestone Road bridge has steeper stream banks and greater adjacent flood plain slopes. The average stream gradient reduces to 30 feet per mile in this portion. In the southern portion of the watershed below Limestone Road bridge, the flood plain becomes very wide with the stream gradient equal to 25 feet per mile.

The climate is characterized by warm, humid summers and damp but not extremely cold winters. Average annual precipitation is 46 inches with the greatest amounts of rainfall generally occurring during July and August and the least amounts occurring in autumn and early winter.

Drainage areas contributing to runoff at locations within the study area are shown in Table 1.

TABLE 1
DRAINAGE AREAS ALONG MILL CREEK

Location	Mileage Above Mouth ^b	Drainage Area	
		Tributary sq. mi.	Total sq. mi.
Upstream of West Branch Mill Creek	7.6	...	1.8
Downstream of West Branch Mill Creek	7.6	0.8	2.6
U.S.G.S. Partial Record Gage Near Hockessin, Delaware (At Brackenville Rd.)	6.8	...	4.2
Upstream of Stoney Batter Rd.	4.6	...	7.4
Downstream of Limestone Rd.	3.1	...	9.5
Upstream of Confluence with Unnamed Tributary	1.3	...	10.4
Downstream of Confluence with Unnamed Tributary	1.3	1.6	12.0
Confluence with White Clay Creek	0	...	12.7

Developments in the Flood Plain

Most of the flood plain is sparsely occupied although there has been some development. Encroachment on the flood plain has occurred in the southern portion of the watershed below Limestone Road bridge, where the suburban area along Delaware Routes 2 and 7 has been expanding. The gently sloping flood plain land in this region is occupied by several developments. Delaware Park Race Track near the confluence of Mill Creek with White Clay Creek is affected by floods on either or both creeks. Further north in this same region, several residences, three commercial establishments, two small industries, a trailer park and a summer camp facility are located in the flood plain. In the central portion of the watershed above Limestone Road, Mill Creek Road runs parallel to the creek for roughly 2 miles and is affected by floodflow over and around bridges. Few homes are located on the relatively narrow flood plain in the northern portion of the watershed near Hockessin.

FLOOD SITUATION

Sources of Data and Records

The U.S. Geological Survey maintains a partial record stream gaging station on Mill Creek near Hockessin, Delaware. Since the record of this gage is only seven years in length, other gaging records in the general area were useful in determining the occurrence and magnitude of future floods.

To supplement the records at the gaging stations, newspaper files, historical documents and records were searched for information concerning past floods. These records have developed a knowledge of floods which have occurred on Mill Creek.

Maps prepared for this report were based on U.S. Geological Survey quadrangle sheets entitled "Newark East, Delaware, 1953" and "Kennett Square, Delaware, 1968". Structural data on bridges and culverts were obtained by field surveys performed by personnel from the Philadelphia District. The Soil Conservation Service, Dover, Delaware, provided cross sectional information.

Flood Season and Flood Characteristics

Records of nearby stream gaging stations indicate the primary flood season to be July, August and September — the season of hurricane and thunderstorm activity. Minor floods have occurred during winter when snowmelt has combined with heavy rainfall. During floods, stages can rise from normal heights to extreme flood peaks in a relatively short period of time with high velocities in the stream channel. At Mill Creek's confluence, high stages of flooding on White Clay Creek can cause a backwater condition on Mill Creek. This "backwater effect" would produce flood peaks on Mill Creek with low velocities of flow.

Factors Affecting Flooding and Its Impact

Obstructions to floodflows - Natural obstructions to floodflows include trees, brush and other vegetation growing along the stream banks in floodway areas. Man-made encroachments on or over the streams such as dams, bridges and culverts, can also create more extensive flooding than would otherwise occur. Natural obstructions to floodflows are shown on Figures 1 through 3. A bridge obstruction to floodflows is illustrated in Figure 4.

During floods, trees, brush and other vegetation growing in floodways impede floodflows, thus creating backwater and increased flood heights. Trees and other debris may

be washed away and carried downstream to collect on bridges and other obstructions to flow. As floodflow increases, masses of debris break loose and a wall of water and debris surges downstream until another obstruction is encountered. Debris may collect against a bridge until the hydraulic load exceeds the structural capacity and the bridge is destroyed. The limited flow capacity of obstructive bridges or culverts, debris plugs at the culvert mouth or a combination of these factors retard floodflows resulting in flooding upstream, erosion around the culvert entrance and bridge approach embankments and possible damage to the overlying road bed.

In general, obstructions restrict floodflows and result in overbank flows and unpredictable areas of flooding; destruction of or damage to bridges and culverts; and, an increased velocity of flow immediately downstream. It is impossible to predict the degree or location of the accumulation of debris; therefore, for the purpose of this report, it was necessary, in the development of the flood profiles, to assume that there would be no accumulation of debris to clog any of the bridge or culvert openings.

Two dams are located on Mill Creek. These dams have no flood control capacity, thus they will not affect floodflows.

Mill Creek and the West Branch are spanned by twenty-seven bridges. Pertinent information on those bridges, most of which are obstructive to floodflows, can be found in Table 6.

Flood damage reduction measures - There are no existing or authorized flood control projects on Mill Creek; however, New Castle County has recently passed an ordinance prohibiting the filling in of flood plain areas and construction on flood plain areas. Although this ordinance will not actually reduce flood damages, it will effectively eliminate increasing damages which are associated with flood plain encroachments.

Other factors and their impacts - The impact of flooding along Mill Creek can be affected by the ability of local residents to anticipate and effectively react to a flood emergency. Efficient flood warning and forecasting systems can give home owners, business and industry valuable time to remove damageable materials from low-lying areas. Although there is little storage of floatable materials on the flood plain of Mill Creek, increased damages to downstream areas could be reduced if floatable materials stored on the flood plain could be removed before being carried downstream to block bridge and culvert openings. Implementation of effective flood fighting and emergency evacuation plans can further reduce flood damages and the incidence of personal injury and death once the creek has reached flood stage.

Flood warning and forecasting - The National Oceanic and Atmospheric Administration (NOAA) maintains a year-round surveillance of weather conditions at the



FIGURE 1 - Debris deposited by a recent flood would be obstructive to floodflows.



FIGURE 2 - Debris build up in channel, resulting from a toppled tree, will be obstructive to floodflows.



FIGURE 3 - Silt deposit beginning to form and clog right bridge opening.

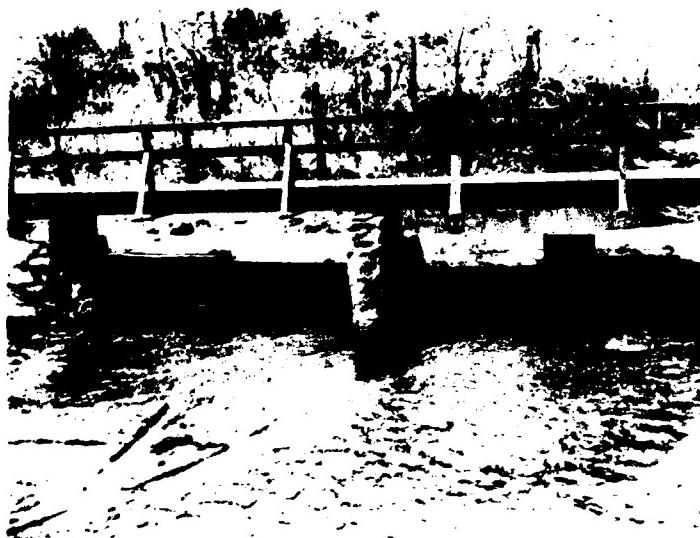


FIGURE 4 - Combination foot bridge and road bridge at West End Neighborhood Center Camp obstructs floodflows.

Wilmington, Delaware, and Philadelphia, Pennsylvania, airports. Flood warnings and anticipated weather conditions are issued by the National Weather Service to the city officials, radio and television stations, and the local press media for further dissemination to residents of the area.

Flood fighting and emergency evacuation plans - Although there are no formal flood fighting or emergency evacuation plans for the Mill Creek watershed, provisions for alerting area residents through local communications media and coordination operations for New Castle County are accomplished by the County Civil Defense Office. This office maintains communications with the State Civil Defense Headquarters and the National Weather Service and establishes a "flood watch" during the earliest stages of a flood threat. Flood fighting, evacuation and rescue activities are coordinated on a county-wide basis with local public agencies.

PAST FLOODS

Summary of Historical Floods

Floods of large magnitude have occurred in 1962, 1963, 1966, 1967, 1969 and 1972. The greatest flood of record for Mill Creek occurred on July 28, 1969. On the same date, Red Clay Creek reached its second highest recorded level.

Flood Records

Information on historical floods in the Mill Creek area is available from the stream gaging station operated by the U.S. Geological Survey (USGS) since 1966. Supplementary records of floods in other areas are available from stream gages on Red Clay and White Clay Creeks. The USGS has records of the same flood events on Mill Creek, Red Clay and White Clay Creeks. The peak record of the Mill Creek Gage, Table 3 lists, in order of decreasing discharge, the highest recorded floods from the longer gage records. A search of historical documents and newspaper files were made for additional information. Interviews were conducted to compile information on the flood history of Mill Creek.

TABLE 2
COMPARISON OF PEAK DISCHARGES AT U.S.G.S. GAGING STATIONS
Mill Creek and Vicinity
(1966 to 1972)

Date of Peak Discharge	U.S.G.S. Gaging Stations Estimated Peak Discharges			
	Mill Creek at Hockessin Sta. 4792 cfs	Red Clay Creek Near Wooddale Sta. 4800 cfs	White Clay Creek Above Newark Sta. 4785 cfs	White Clay Creek Near Newark Sta. 4790 cfs
June 22, 1972	687	4,120	10,200	9,080
February 7, 1971	524	2,430	3,490	4,930
April 2, 1970	579	2,100	2,560	3,000
July 28, 1969	2,100	4,500	2,430	-
January 14, 1968	272	1,750	1,930	2,360
August 10, 1967	727	2,460	4,540	6,640
February 13, 1966	504	3,000	3,910	3,770

(a) Peak occurred on February 8, 1971.

(b) No record available from July 22 through August 29, 1969.

TABLE 3
RECORD FLOODS AT SELECTED U.S.G.S. GAGING STATIONS
Vicinity of Mill Creek

Order of Magnitude	U.S.G.S. Gaging Stations		
	Red Clay Creek Near Wooddale Sta. 4800	White Clay Creek Above Newark Sta. 4785	White Clay Creek Near Newark Sta. 4790
1	September 12, 1960	June 23, 1972	July 5, 1937
2	July 28, 1969	August 10, 1967	June 23, 1972
3	June 22, 1972	August 18, 1955	August 10, 1967
4	August 18, 1955	March 7, 1967	September 12, 1960
5	March 7, 1967	February 13, 1966	August 18, 1955

Flood Descriptions

July 9, 1952 - Local storm activity produced intense flooding in many locations throughout New Castle County. Wilmington, Delaware, reported that 6.53 inches of rain fell between 7:30 A.M. and 2:30 P.M. The flood on Red Clay Creek which resulted from these storms ranked as the seventh highest flood of record. The resulting flood on Mill Creek caused the evacuation of campers at both resident camps near Hockessin.

EXCERPTS FROM THE WILMINGTON EVERY EVENING JOURNAL (a)
JULY 9, 1952

RED CROSS HELPS 120 FLEE HOMES IN SUBURBS MANY ROADS BLOCKED AS TORRENTS END DROUGHT END IS NOT IN SIGHT

Young Campers Saved with Aid of Ropes

Torrents of rain last night and today caused critical floods in one suburban area, detoured much Wilmington and outlying traffic and required the evacuation of hundreds of residents and some 110 youthful campers in New Castle County.

Summer Camp Flooded

In addition to the rowboat removal of the 60 Brack-Ex families, most of the residents of an eight block area on Brighton, Marion, and Brackville Aves., one of the most critical events of the day occurred at the camps in Hockessin operated by the Boys' Club and the Family Society.

More than 110 youngsters at these resident centers were removed by bus, station wagon, and car.

In the case of the 64 boys at Camp Mathtoon of the Boys' Club, cabins were half-filled with water and counselors had to throw a rope across the stream and cling to it while carrying the boys to safety.

The Boys' Club and Family Society Camps are in the Hockessin-Marshalltown-Limestone Road Valley Section where many small creeks and streams overflowed, bridges were washed out and the fallen trees blocked traffic routes.

(a) Simulated from microfilm copy

Belongings Left Behind

The 64 boys at Mattahoon began the evacuation early this morning. They were taken from cabins where water covered the floors, through flooded farmlands, and across streams. All belongings were left behind.

The Family Society's center in Hockessin began its removal just before noon, and much

rerouting of buses, station wagons, and cars were necessary.

Creeks overflowing added to the miseries of the lowlands near Stanton, where several acres were flooded. The grounds of Delaware Park were covered and the Penna. Railroad underpass nearby was being pumped of three feet of water by State Highway Department Crews.

August 18, 1955 - Hurricane Diane swept through the eastern coastal states only five days after Hurricane Connie brought major flooding. Scattered rainfall falling on already-saturated watersheds resulted in floods of sometimes even greater magnitude than experienced during Hurricane Connie. The Red Clay Creek flood level reached its fourth highest flood of record as a result of these runoff conditions.

EXCERPTS FROM THE WILMINGTON EVERY EVENING JOURNAL, AUGUST 19, 1955, RELATIVE TO THE FLOOD OF AUGUST 18, 1955^(a)

RAINS FLOOD HOMES, HIGHWAYS IN AREA 22 DEAD AS STORM SWEEPS 9 EASTERN STATES

Torrential rains swept across northern Delaware last night sending streams and creeks roaring over their banks.

Swirling floodwaters engulfed homes, swept over roads and streets, threatened electric

power, and nearly caused three deaths.

The rain also struck the Hockessin area flooding several small streams. The Old Lancaster Pike was under a foot or more of water in some places.

September 12, 1960 - Hurricane Donna brought 5.62 inches of rainfall in a 24-hour period to the New Castle County area. The flood on Red Clay Creek reached the highest level in its recorded history.

^(a) Simulated from microfilm copy.

**EXCERPTS FROM THE WILMINGTON EVERY EVENING JOURNAL
SEPTEMBER 12, 1960 (a)**

DONNA RIPS STATE WITH WIND, RAIN HUNDREDS FORCED TO FLEE, DAMAGE HEAVY

A howling Hurricane Donna lashed Delaware with wind, water and wreckage today and proceeded northeast.

The Stanton underpass of the Penna. Railroad on Delaware Route 7 was under high water and blocked to traffic until the tide receded.

**EXCERPTS FROM THE WILMINGTON EVERY EVENING JOURNAL,
SEPTEMBER 13, 1960, RELATIVE TO THE FLOOD OF SEPTEMBER 12, 1960 (a)**

STATE STARTS CLEAN UP AFTER DONNA MOST UTILITY LINES FIXED OVERNIGHT

Delawareans today began cleaning up the debris and counting the damage left by Hurricane Donna.

Most of the damage to New Castle County was caused by the overflow of every stream, creek and river.

Highways throughout the state were flooded or closed. Governor Printz Boulevard was under four feet of water, the Red Clay Creek Bridge between Stanton and Newport was almost washed away, State Route 7 had sections flooded and there were floods on Old Capitol Trail, Newark-Olgetown Rd. and many other highways.

July 28, 1969 - Intense rainstorm activity in the Red Clay and Mill Creek watersheds produced very high floodflows. The Red Clay Creek Gage at Wooddale, Delaware, recorded its second highest flood while Mill Creek reached its highest flow in six years.

Newspaper accounts of flooding concentrated entirely on the damages caused by Red Clay Creek; however, interviews with camp counselors and local residents confirmed that Mill Creek had reached notable stages. At Camp Mattahoon and the West End

(a) Simulated from microfilm copy.

Neighborhood Center Camp, the high flood waters caused some difficulties. Rising flood waters cut off the main access road bridge to one camp and isolated some campers for an hour or two. Counselors at the other camp fought to keep camp bridges clear of debris in efforts to save the bridges from destruction. In spots, Mill Creek Road was impassable.

June 22, 1972 - Damages from floods in the northeastern United States caused by Tropical Storm "Agnes" caught the national headlines; however, Delaware was one of the more fortunate states, with damages far below those experienced in other areas such as Central Pennsylvania. Although "Agnes" had produced the maximum flood of record on the White Clay Creek, Mill Creek experienced very little damage. The mood of many Delawareans was summed up by this quote from the Newark, Delaware, WEEKLY POST: "Agnes is considered by many to be the worst storm ever to hit the Eastern United States, leaving thousands of dollars worth of damage in her wake. She decided not to make a lengthy stop-over in Delaware on her travels northward. For that we are grateful."

FUTURE FLOODS

Floods of the same or larger magnitude as those that have occurred in the past could occur in the future. Larger floods have been experienced in the past on streams with similar geographical and physiographical characteristics as those found in the study area. Similar combinations of rainfall and runoff which caused these floods could occur in the study area. Therefore, to determine the flooding potential of the study area, it was necessary to consider storms and floods that have occurred in regions of like topography, watershed cover, and physical characteristics. Discussion of the future floods in this report is limited to those that have been designated as the Intermediate Regional Flood and the Standard Project Flood. The estimates of the Intermediate Regional and the Standard Project Floods as presented in this report are based on the existing development of the watershed since future changes within the basin cannot be accurately predicted. The Standard Project Flood represents a reasonable upper limit of expected flooding in the study area. The Intermediate Regional Flood may reasonably be expected to occur more frequently although it will not be as severe as the infrequent Standard Project Flood.

Intermediate Regional Flood

The Intermediate Regional Flood is defined as one that occurs once in 100 years on the average, although it could occur in any year. The peak flow of this flood was developed from a regional analysis of streamflow records. Peak flows thus developed for the Intermediate Regional Flood at selected locations in the study area are shown in Table 4.

Standard Project Flood

The Standard Project Flood is defined as a major flood that can be expected to occur from a severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical area in which the study area is located, excluding extremely rare combinations. The Corps of Engineers, in cooperation with the NOAA Weather Service, has made comprehensive studies and investigations based on the past records of experienced storms and floods and has developed generalized procedures for estimating the flood potential of streams. Peak discharges for the Standard Project Flood at selected locations in the study area are shown in Table 4. Discharge hydrographs for the Standard Project Flood at the mouth of Mill Creek and at the U.S. Geological Survey Gage near Hockessin are shown on Plate 11. The relative water surface elevations for the Intermediate Regional Flood and the Standard Project Flood are shown on Plates 7 through 9.

TABLE 4
**PEAK FLOWS FOR THE INTERMEDIATE REGIONAL AND
 STANDARD PROJECT FLOODS**

Location	Mileage Above Mouth	Intermediate Regional Flood Discharge cfs	Standard Project Flood Discharge cfs
At Mouth	0	4,375	5,200
Downstream of Unnamed Tributary	1.3	4,145	4,710
Downstream of Limestone Rd.	3.1	3,850	4,310
Downstream of Stoney Batter Rd.	4.6	2,960	3,420
U.S.G.S. Gage at Hockessin	6.8	2,300	2,500
Downstream of West Branch Mill Creek	7.6	1,210	1,360

Table 5 shows comparisons of flood elevations at Hockessin, Delaware, for the Intermediate Regional and the Standard Project Floods with the highest recorded flood, July 28, 1969.

TABLE 5
COMPARISON OF FLOOD ELEVATIONS
 Mill Creek at Hockessin, Delaware
 U.S.G.S. Gage

Flood	Elevation Ft. - Mean Sea Level Datum
Standard Project	227.0
Intermediate Regional	226.8
July 28, 1969	225.1 ^(a)

(a) Culvert reconstructed after 1969 flood.

Frequency

A frequency curve of peak flows was developed from available recorded annual peaks. The curve presents the frequency of floodflows up to the magnitude of once in 100 years (Intermediate Regional Flood). Frequencies of floods equivalent to the Standard Project Flood and larger can be obtained through extrapolation of the curve, but it is not practical to assign a frequency to such large flows as their occurrence is so extremely rare. The curve, which is available upon request, reflects the judgment of engineers who have

studied the area and are familiar with the region; however, it must be regarded as approximate and should be used with caution in connection with any planning of flood plain use.

Hazards of Large Floods

The extent of damage caused by any flood depends on the topography of the area flooded, depth and duration of flooding, velocity of flow, rate of rise, and developments in the flood plain. An Intermediate Regional Flood or Standard Project Flood on Mill Creek would result in the inundation of residential, commercial, and industrial properties in the study area. Deep floodwater flowing at high velocity and carrying floating debris would create conditions hazardous to persons and vehicles attempting to cross flooded areas. In general, floodwater 3 or more feet deep and flowing at a velocity of 3 or more feet per second could easily sweep an adult person off his feet, thus creating definite danger of injury or drowning. Rapidly rising and swiftly flowing floodwater may trap persons in homes that may be destroyed, or in vehicles that are ultimately submerged or floated. Water lines can be ruptured by deposits of debris and the force of floodwaters, thus creating the possibility of contaminated domestic water supplies. Damaged sanitary sewer lines and sewage treatment plants could result in the pollution of floodwaters creating health hazards. Isolation of areas by floodwater could create hazards in terms of medical, fire, or law enforcement emergencies.

Flooded areas and flood damages - The areas along Mill Creek that would be flooded by the Standard Project Flood are shown on Plate 2 which is also an index map to Plates 3 through 6. Areas that would be flooded by the Intermediate Regional Flood and the Standard Project Flood are shown in detail on Plates 3 through 6. The actual limits of these overflow areas may vary somewhat from those shown on the maps because the 10-foot contour interval and scale of the maps do not permit precise plotting of the flooded area boundaries. The areas that would be flooded by the Intermediate Regional and Standard Project floods include commercial and residential properties, along with associated streets and roads. Considerable damage to the facilities would occur during an Intermediate Regional Flood. However, due to the wider extent, greater depths of flooding, higher velocity flow and longer duration of flooding during a Standard Project Flood, damage would be more severe than during an Intermediate Regional Flood. Plates 7 through 9 show the water surface profiles for the Intermediate Regional and Standard Project Floods. Depth of flow in the channel can be estimated from these illustrations. Cross sections of the flood plain at selected locations, together with the water surface elevation and lateral extent of the Intermediate Regional and the Standard Project Floods are shown on Plate 10.

Obstructions - During floods, debris collecting on bridges and culverts could decrease their carrying capacity and cause greater water depths (backwater effect) upstream of these structures. Since the occurrence and amount of debris are indeterminate factors, only the physical characteristics of the structures were considered in preparing profiles of the Intermediate Regional and Standard Project Floods. Similarly, the maps of flooded areas

show the backwater effect of obstructive bridges and culverts, but do not reflect increased water surface elevation that could be caused by debris collecting against the structures, or by deposition of silt in the stream channel under structures. As previously indicated, there are two dams within the study area which have no flood control capacities nor will they seriously alter flow characteristics of floodwaters. Of the twenty-seven bridges crossing the stream in the study area, most of them are obstructive to the Intermediate Regional Flood and all of them are obstructive to the Standard Project Flood as illustrated by the high water profiles on Plates 7 through 9. Table 6 shows water surface elevations at these bridges.

TABLE 6
ELEVATION DATA
Bridges Across Mill Creek and West Branch Mill Creek

Identification	Mileage Above Mouth	Underclearance Elevation ft. - m.s.l.d.	Water Surface Elevation	
			Intermediate Regional Flood	Standard Project Flood
<u>Mill Creek</u>				
Private Rd.	0.2	12.8	20.6	23.8
Access Rd. to Delaware Park Race Track	0.2	14.7	20.8	23.9
B & O R.R.	0.9	36.6	29.1	30.4
Old Capitol Trail	1.2	28.2	33.7	34.1
Robert Kirkwood Highway, Del. Rt. 2	1.7	49.9	50.1	50.9
Old Milltown Rd.	2.6	86.1	89.0	89.8
Milltown Rd.	2.6	93.9	91.2	92.3
Limestone Rd., Del. Rt. 7	3.1	101.0	104.1	105.5
Camp Mattahoon Foot Br.	3.4	105.7	110.3	110.8
Camp Mattahoon Rd. Br.	3.5	108.7	113.8	114.4
Stoney Batter Rd.	4.6	164.3	165.9	167.4
W. End Neighborhood Center Camp				
Vehicle Bridge	5.6	180.9	186.5	187.7
Foot Bridge	5.6	185.2	186.5	188.0
Mill Creek Rd.	5.7	186.0	188.0	191.0
Private Rd.	6.2	200.3	205.7	206.0
Private Rd.	6.4	212.3	215.8	216.1
Private Foot Br.	6.5	213.2	216.1	216.4
Brackenville Rd.	6.8	222.8	226.8	226.9
Mill Creek Rd.	7.4	230.1	233.9	234.2
Evanson Rd.	7.8	241.5	243.7	244.0
Grant Rd.	8.0	243.1	246.6	246.8
B & O R.R.	8.1	253.9	254.2	254.8

TABLE 6 (Continued)
ELEVATION DATA
Bridges Across Mill Creek and West Branch Mill Creek

Identification	Mileage Above Mouth	Underclearance Elevation <small>ft. - m.s.l.d.</small>	Water Surface Elevation	
			Intermediate Regional Flood	Standard Project Flood <small>ft. - m.s.l.d.</small>
Old Lancaster Pike	8.3	253.4	257.5	257.6
Lancaster Pike, Del. Rt. 41	8.4	254.3	258.2	258.3
McGovern Rd.	9.0	294.4	297.5	297.6
<u>West Branch Mill Creek</u>				
Valley Rd.	0.3	253.3	254.2	257.2
Southwood Rd.	1.2	316.8	320.1	320.8

Velocities of flow - Water velocities during floods depend largely on the size and shape of the cross sections, conditions of the stream, and the bed slope, all of which vary on different streams and at different locations on the same stream. During an Intermediate Regional Flood, velocities of main channel flow in the study area would typically average 8 to 9 feet per second. Water flowing at this rate is capable of causing severe erosion to stream banks and fill around bridge abutments and capable of transporting large objects. It is expected that velocity of main channel flow during a Standard Project Flood would be slightly higher than during an Intermediate Regional Flood. During these floods, the velocity of overbank flow in the study area would average 1 to 2 feet per second. Water flowing at 2 feet per second or less would deposit debris and silt. Table 7 lists the maximum velocities that would occur in the main channel and overbank areas of Mill Creek for selected cross sections during the Intermediate Regional and the Standard Project Floods.

TABLE 7
MAXIMUM VELOCITIES
Mill Creek and West Branch Mill Creek

Location	Mileage Above Mouth	Maximum Average Velocities				
		Intermediate Regional Flood		Standard Project Flood		
		Channel <small>ft/sec.</small>	Overbank <small>ft./sec.</small>	Channel <small>ft/sec.</small>	Overbank <small>ft/sec.</small>	
<u>Mill Creek</u>						
Cross Section:						
9	2.78	8.3	1.6	8.3	1.7	
15	5.38	7.3	1.3	7.6	1.4	
17	6.36	11.6	1.9	11.7	1.9	
24	9.29	10.0	1.8	10.1	1.8	
<u>West Branch Mill Creek</u>						
26	0.47	7.8	1.2	8.5	1.5	
28	1.33	8.4	1.5	11.1	2.1	

Rates of rise and duration of flooding - Intense rainfalls that accompany severe storm fronts usually produce the floods occurring in the Mill Creek basin. There is a time lag of several hours before overbank flooding occurs along the main stream. Floods generally rise slowly and stay out of banks for long periods of time. Table 8 gives the maximum rate of rise, height of rise (from critical stage level to maximum floodflow level), time of rise (time period corresponding to height of rise), and duration of critical stage (period of time flooding is above critical stage level) for the Standard Project Flood and the floods of July 28, 1969; August 10, 1967; and, June 22, 1972, at Hockessin, Delaware.

TABLE 8
RATES OF RISE AND DURATION OF PAST AND FUTURE FLOODS
U.S.G.S. Gage Near Hockessin, Delaware

Flood	Discharge cfs	Maximum Rate of Rise ft/hr.	Height of Rise ft.	Time of Rise hrs.	Duration of Critical Stage hrs.
Standard Project	2,500	2.6	7.7	6.0	26.0
July 28, 1969	2,100	4.3	5.8	1.8	4.8
August 10, 1967	727	0.9	1.6	1.9	4.8
June 22, 1972	687	2.3	2.5	1.2	6.0

NOTE: The above table reflects characteristics of floods resulting from rainfall distributions of various durations and intensities. The Standard Project Flood results from rainfall of long duration.

Photographs, future flood heights - The levels that the Intermediate Regional and Standard Project Floods are expected to reach at various locations along Mill Creek are indicated on the following photographs.



FIGURE 5 - Future flood heights at entrance road to Delaware Park Race Track

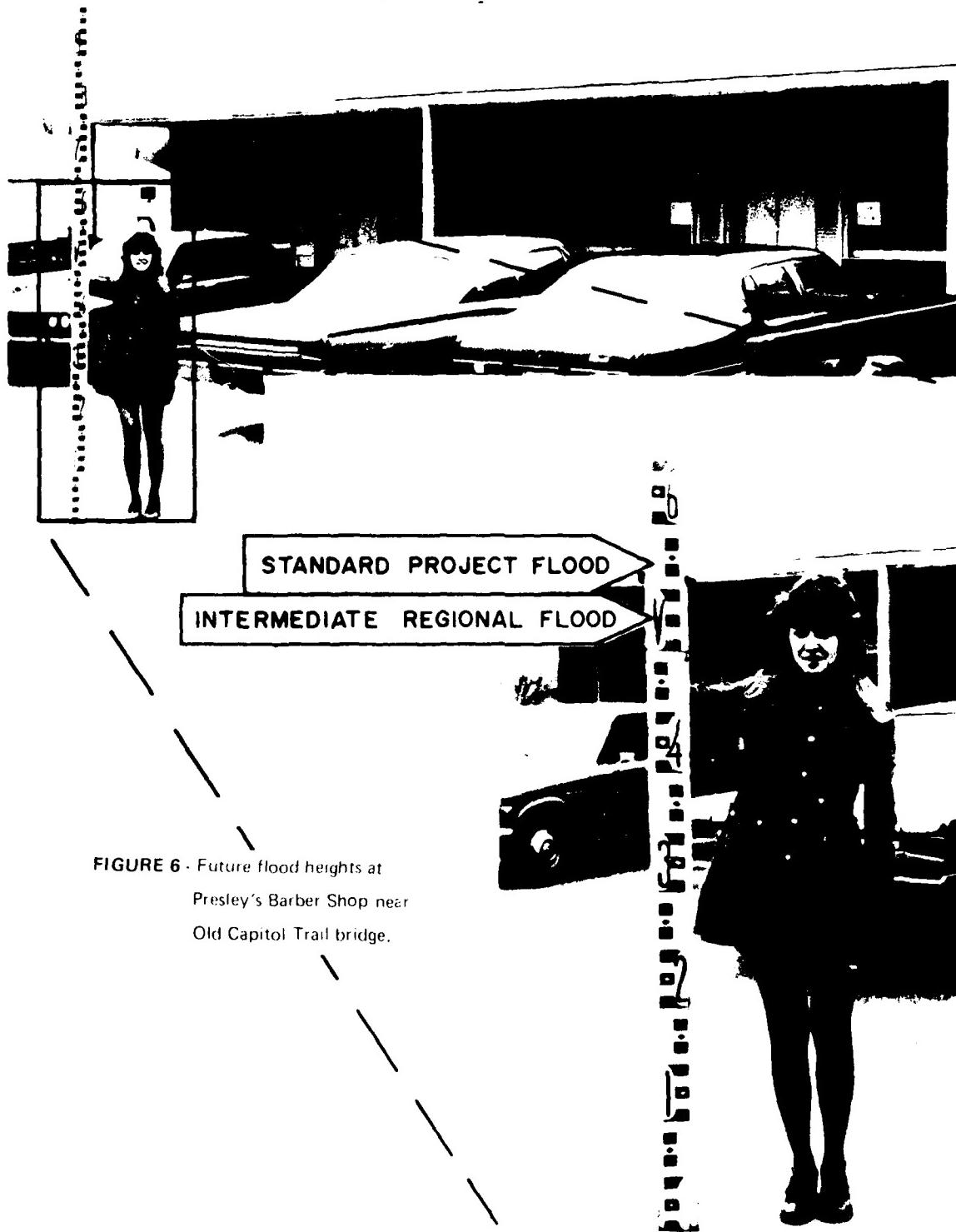




FIGURE 7 - Future flood heights at West End Neighborhood Center Camp.

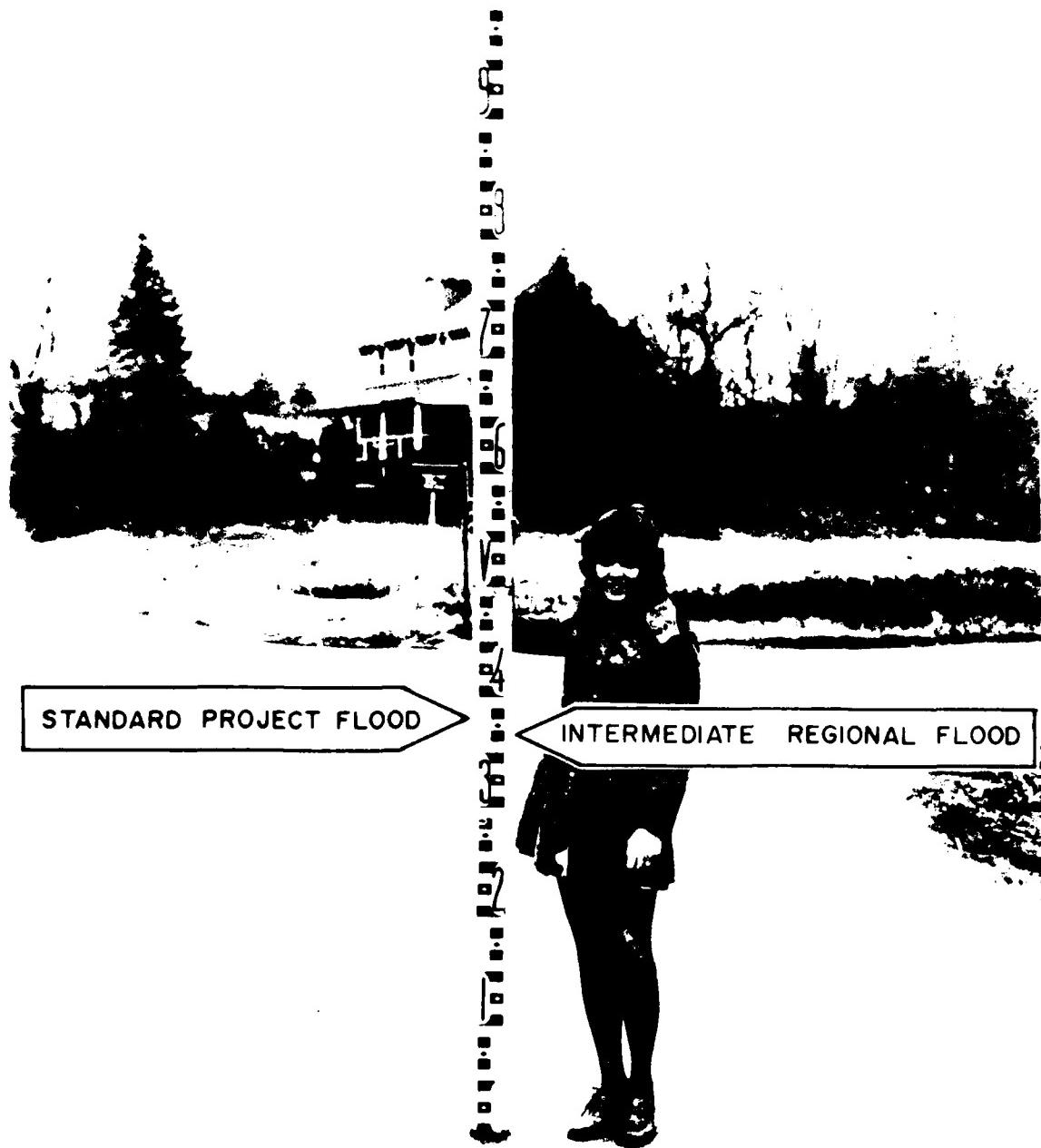


FIGURE 8 - Future flood heights near Brackenville Road bridge.



FIGURE 9 - Future flood heights at Mill Creek Road bridge



FIGURE 10 Future flood heights at Old Lancaster Pike bridge

GLOSSARY

Backwater. The resulting high water surface in a given stream due to a downstream obstruction or high stages in an intersecting stream.

Flood. An overflow of lands not normally covered by water and that are used or usable by man. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, ocean, lake, or other body of standing water.

Normally a "flood" is considered as any temporary rise in streamflow or stage, but not the ponding of surface water, that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions, rise of ground water coincident with increased streamflow, and other problems.

Flood Crest. The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Plain. The areas adjoining a river, stream, watercourse, ocean, lake, or other body of standing water that have been or may be covered by floodwater.

Flood Profile. A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific flood, but may be prepared for conditions at a given time or stage.

Flood Stage. The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Hurricane. An intense cyclonic windstorm of tropical origin in which winds tend to spiral inward in a counterclockwise direction toward a core of low pressure, with maximum surface wind velocities that equal or exceed 75 miles per hour (65 knots) for several minutes or longer at some points. Tropical storm is the term applied if maximum winds are less than 75 miles per hour.

Hydrograph. A graph showing flow values against time at a given point, usually measured in cubic feet per second. The area under the curve indicates total volume of flow.

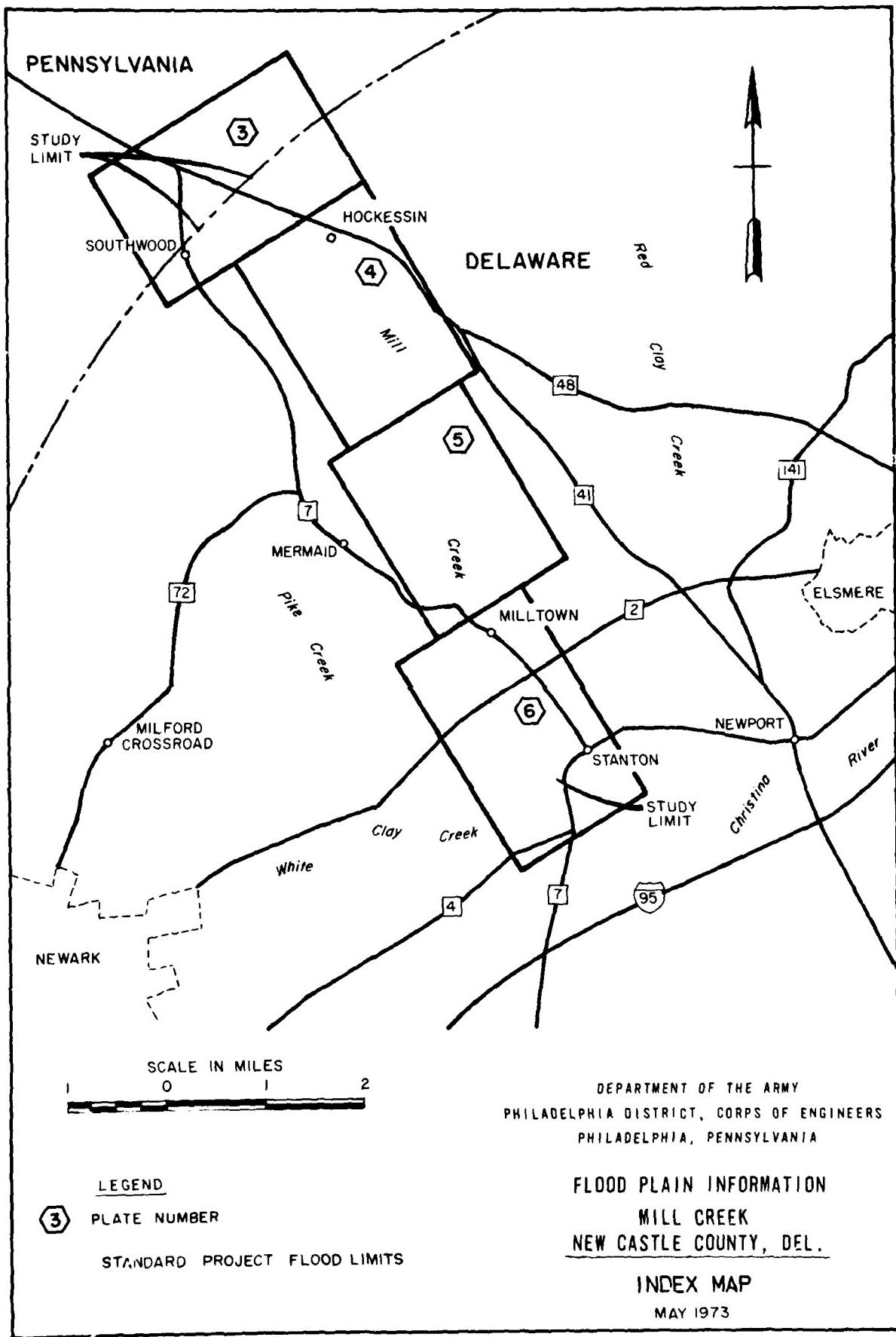
Intermediate Regional Flood. A flood having an average frequency of occurrence in the order of once in 100 years although the flood may occur in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the general region of the watershed.

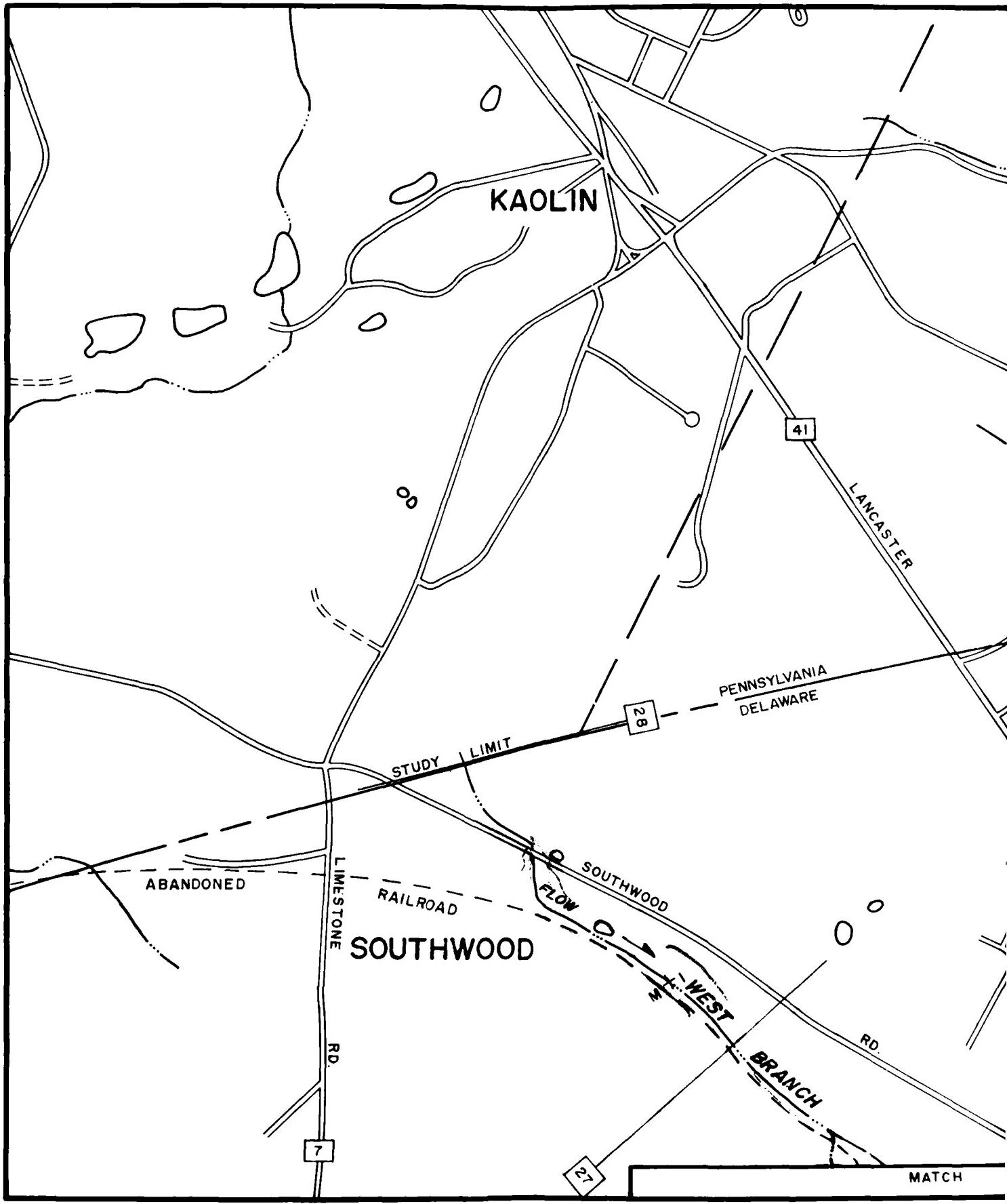
Left Bank. The bank on the left side of a river, stream, or watercourse, looking downstream.

Right Bank. The bank on the right side of a river, stream, or watercourse, looking downstream.

Standard Project Flood. The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40-60 percent of the Probable Maximum Floods for the same basins. As used by the Corps of Engineers, Standard Project Floods are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.

Underclearance Elevation. The elevation at the top of the opening of a culvert, or other structure through which water may flow along a watercourse.





OVER

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NOTES

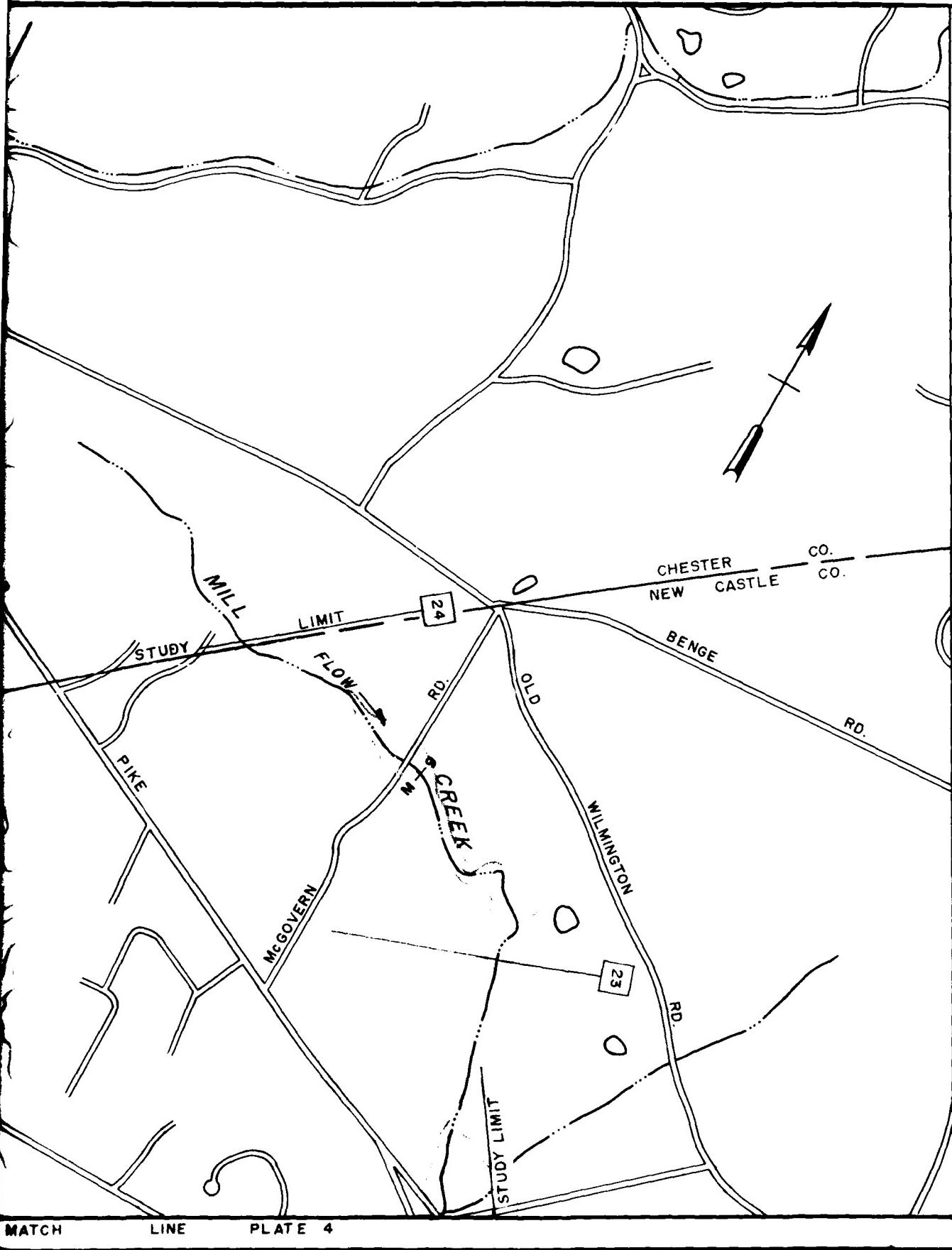
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2. LIMITS OF OVERFLOW ACTUAL LOCATION IN THE REPORT.
3. AREAS OUTSIDE THE SUBJECT TO FLOOD
4. MINIMUM CONTOUR

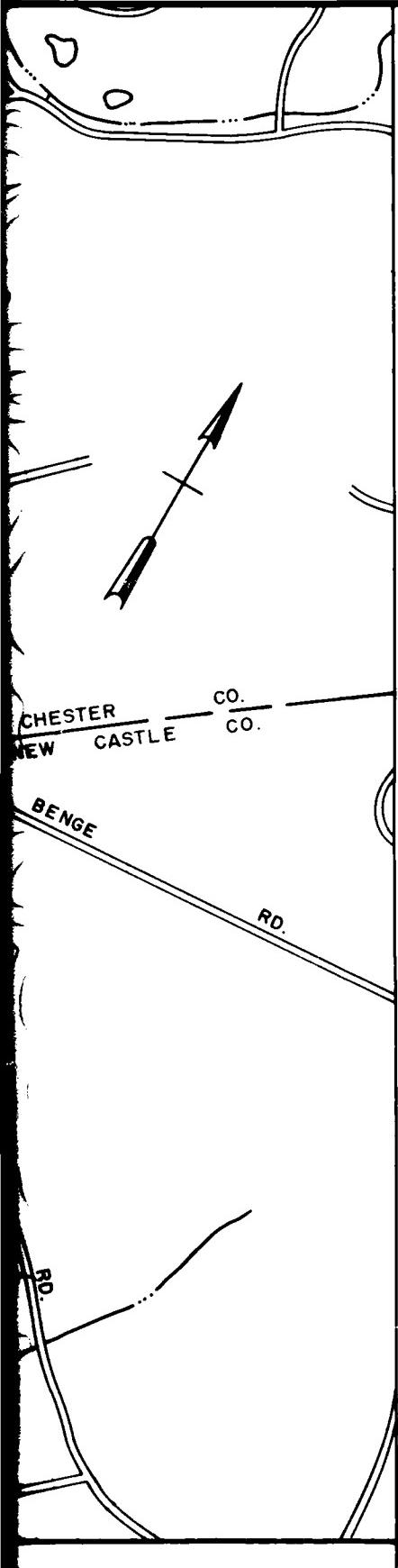
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LEGEND

OVERFLOW LIMITS

{	INTERMEDIATE	}	STANDARD
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	FLOOD		FLOOD

M+9 MILES ABOVE MOUTH

[27] CROSS SECTION

GROUND ELEVATION IN FEET (U.S.C.
G.S. 1929 ADJ.) SEA LEVEL DATUM

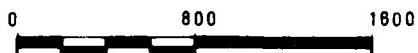
— — — COUNTY LIMITS

[41] STATE ROUTE

NOTES

1. MAP BASED ON U.S.G.S. 7.5 MIN. QUADRANGLE SHEETS: NEWARK EAST, DEL. 1953 & KENNEDY SQUARE, PA. 1968. MINOR ADDITIONS AND ADJUSTMENTS MADE BY CORPS OF ENGINEERS.
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT.
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF.
4. MINIMUM CONTOUR INTERVAL IS 20 FT.

SCALE IN FEET



DEPARTMENT OF THE ARMY

PHILADELPHIA DISTRICT, CORPS OF ENGINEERS

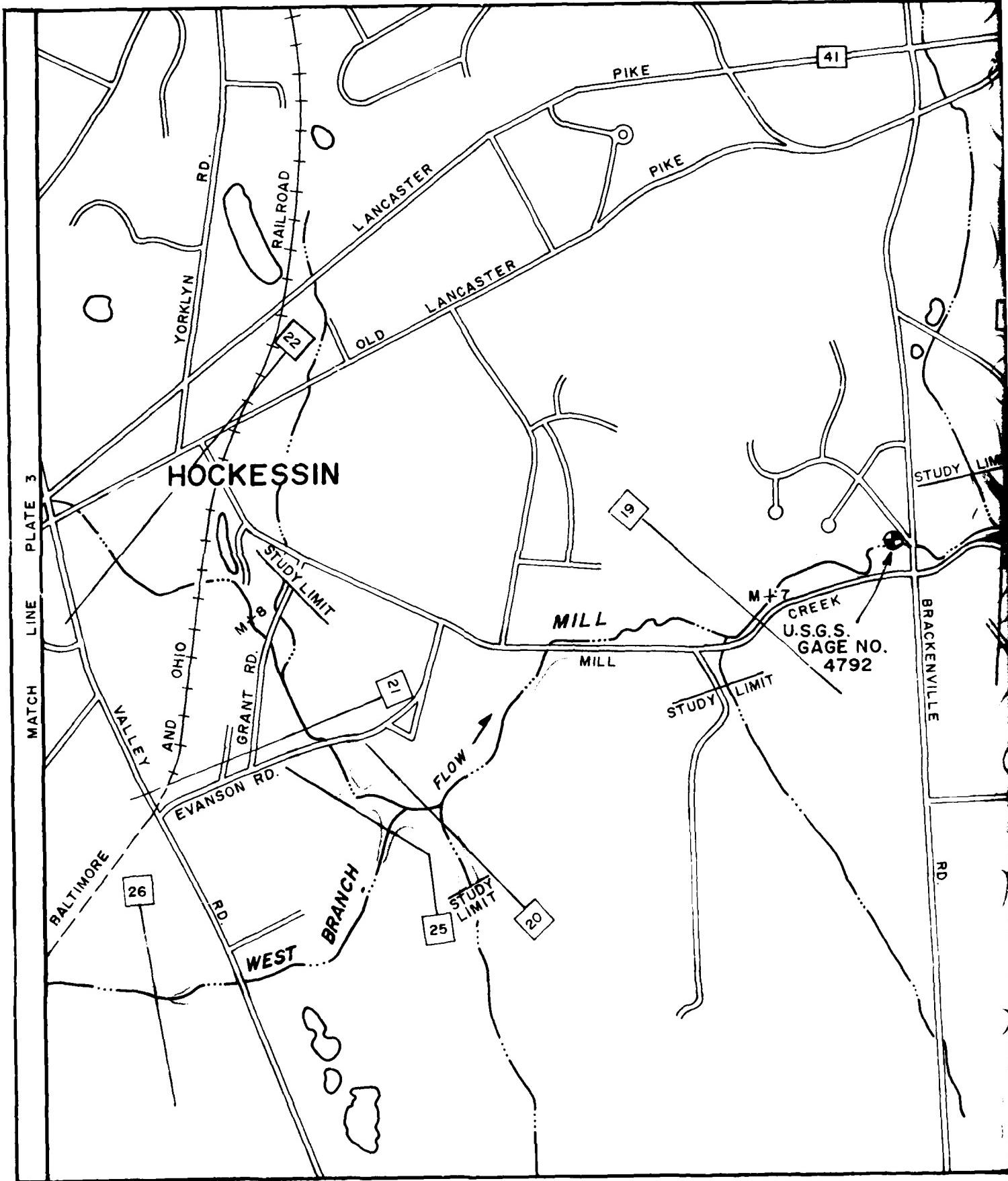
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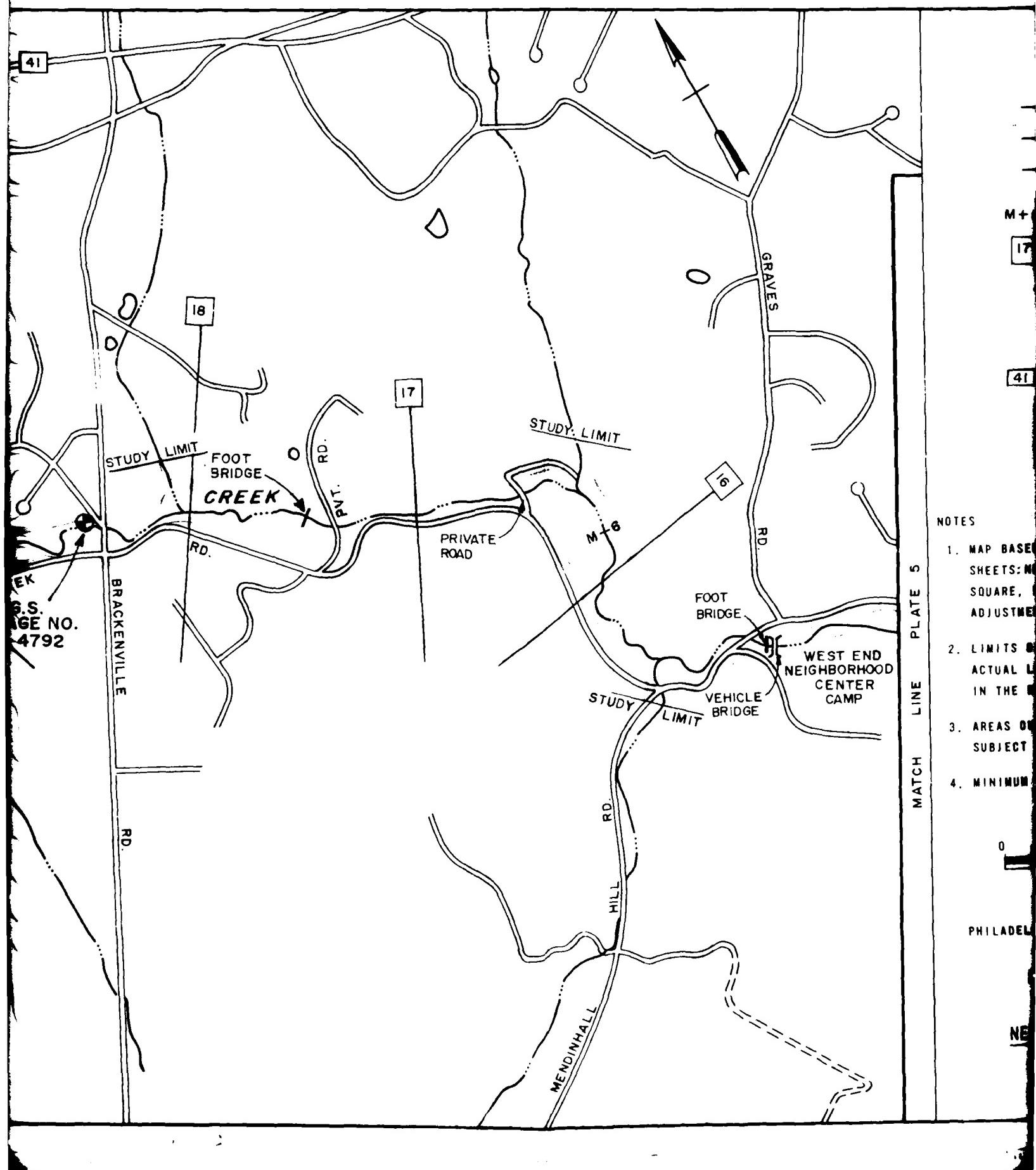
FLOOD PLAIN INFORMATION

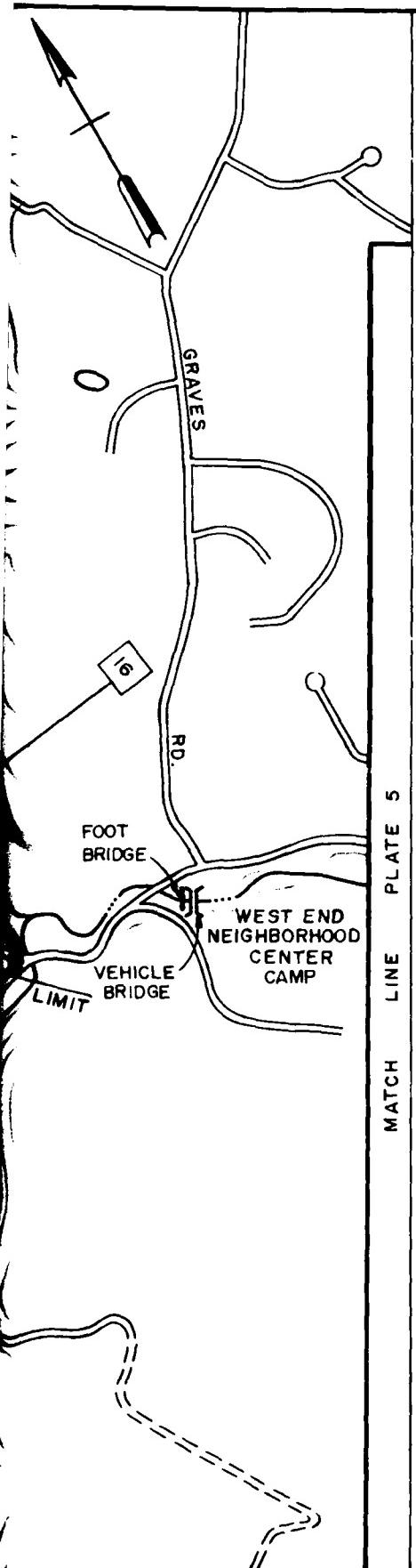
MILL CREEK
NEW CASTLE COUNTY, DELAWARE

FLOODED AREAS

MAY 1973







LEGEND
OVERFLOW LIMITS

INTERMEDIATE	STANDARD
REGIONAL	PROJECT
FLOOD	FLOOD

M + 6 MILES ABOVE MOUTH

[17] CROSS SECTION

▲ GROUND ELEVATION IN FEET (U.S.C.
G.S. 1929 ADJ.) SEA LEVEL DATUM

[41] STATE ROUTE

NOTES

- MAP BASED ON U.S.G.S. 7.5 MIN. QUADRANGLE SHEETS: NEWARK EAST, DEL. 1953 & KENNEDY SQUARE, PA. 1988. MINOR ADDITIONS AND ADJUSTMENTS MADE BY CORPS OF ENGINEERS.
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- MINIMUM CONTOUR INTERVAL IS 20 FT.

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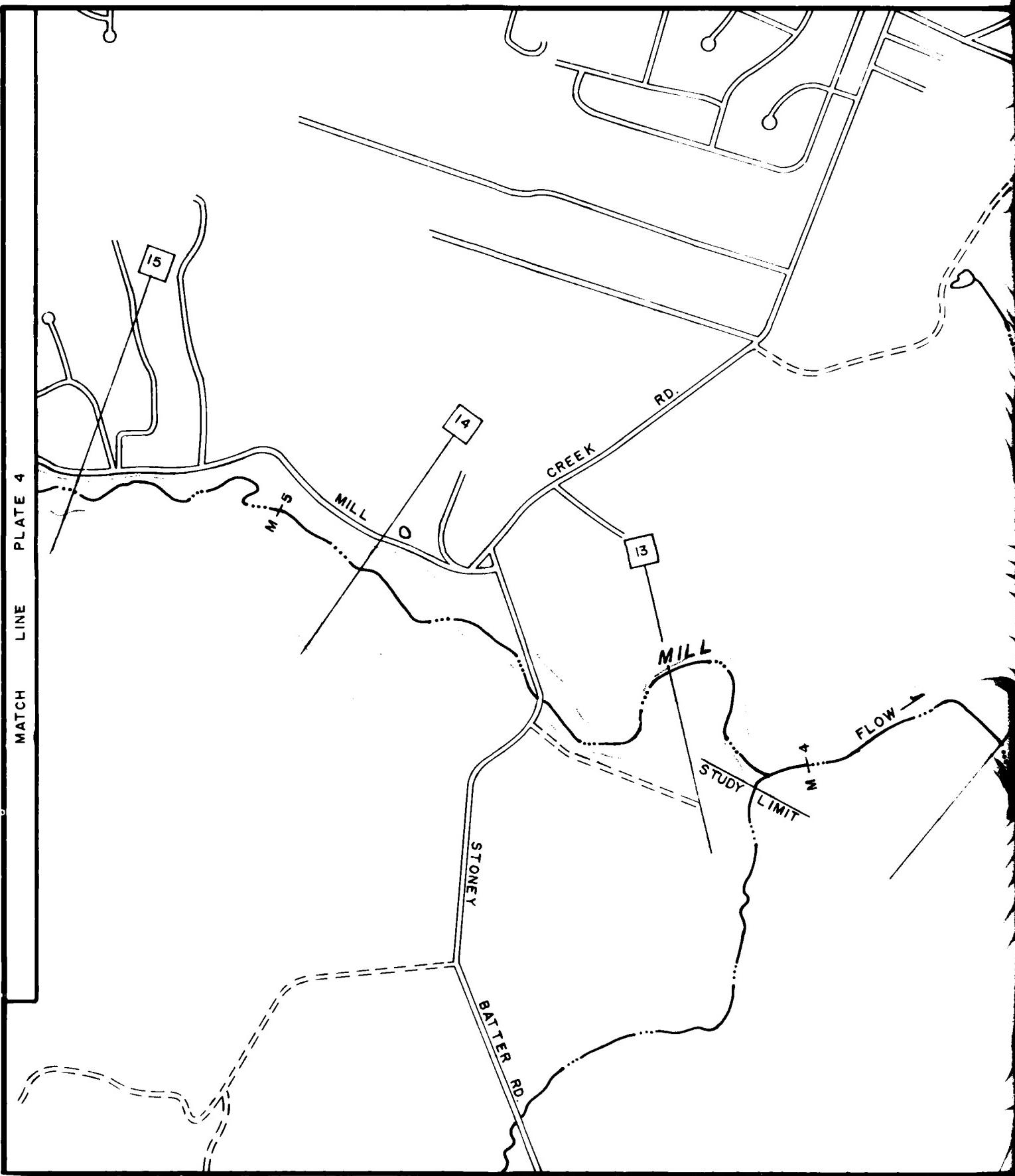
DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
FLOOD PLAIN INFORMATION

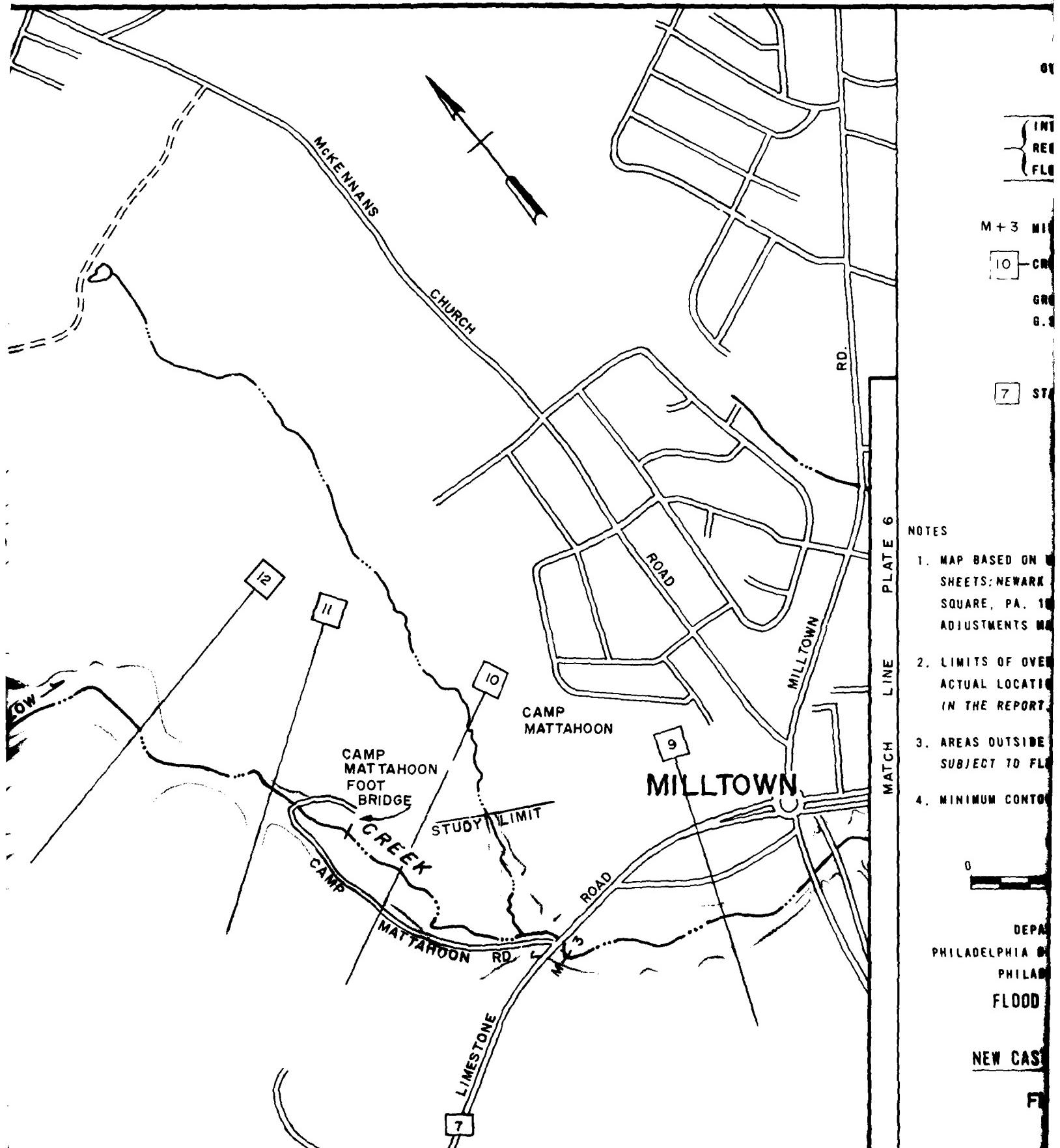
MILL CREEK
NEW CASTLE COUNTY, DELAWARE

FLOODED AREAS

MAY 1973

MATCH LINE PLATE 4





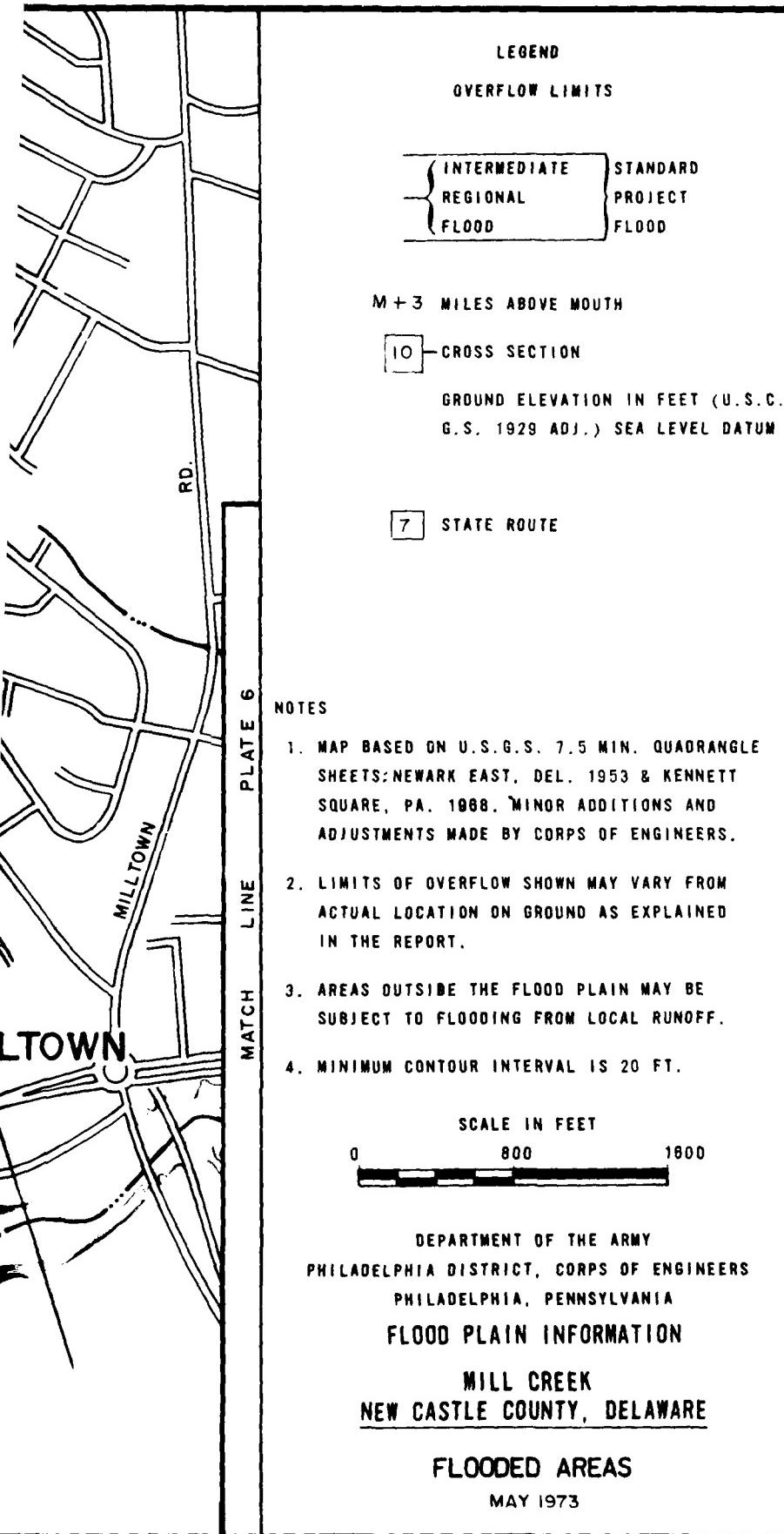
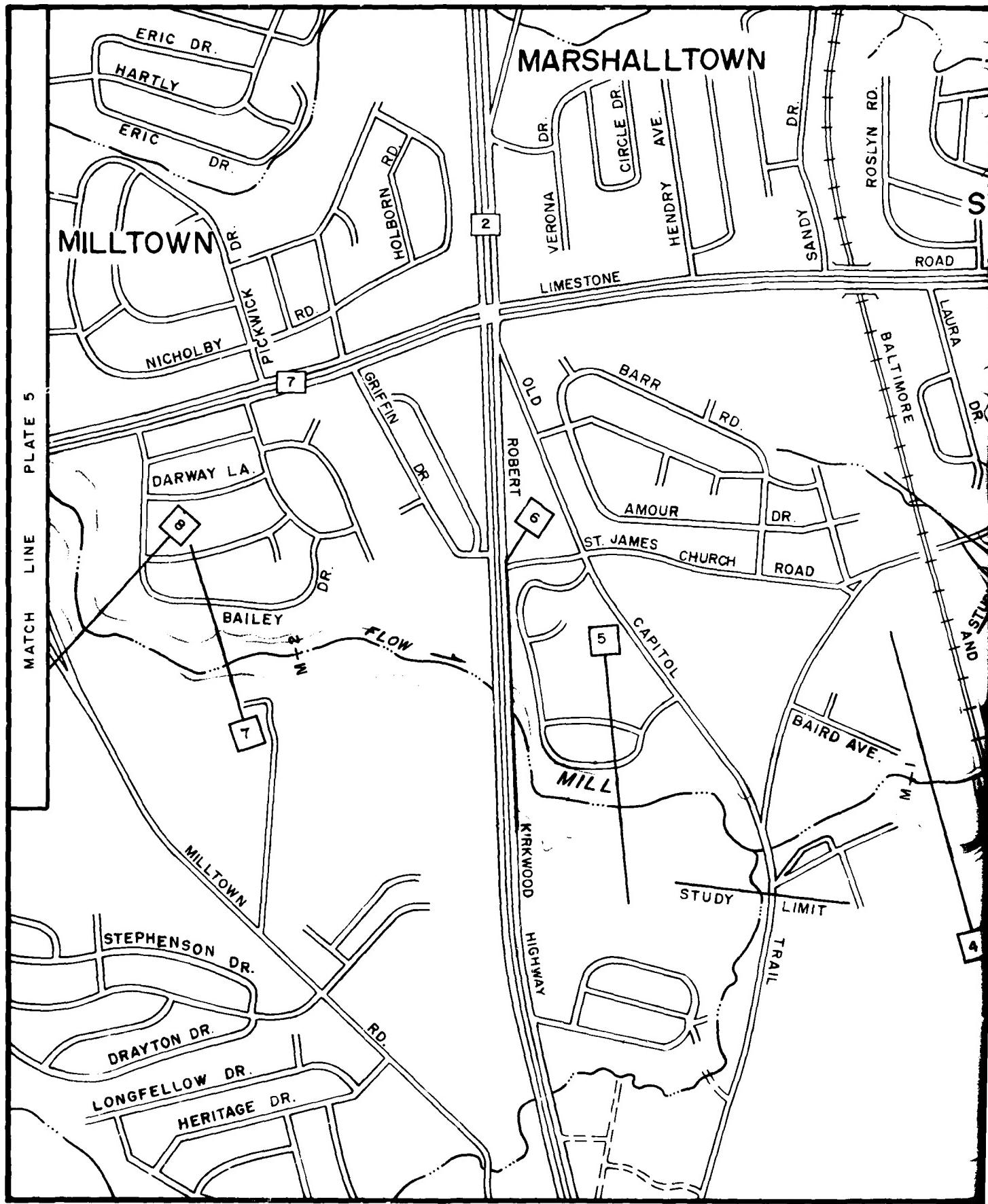
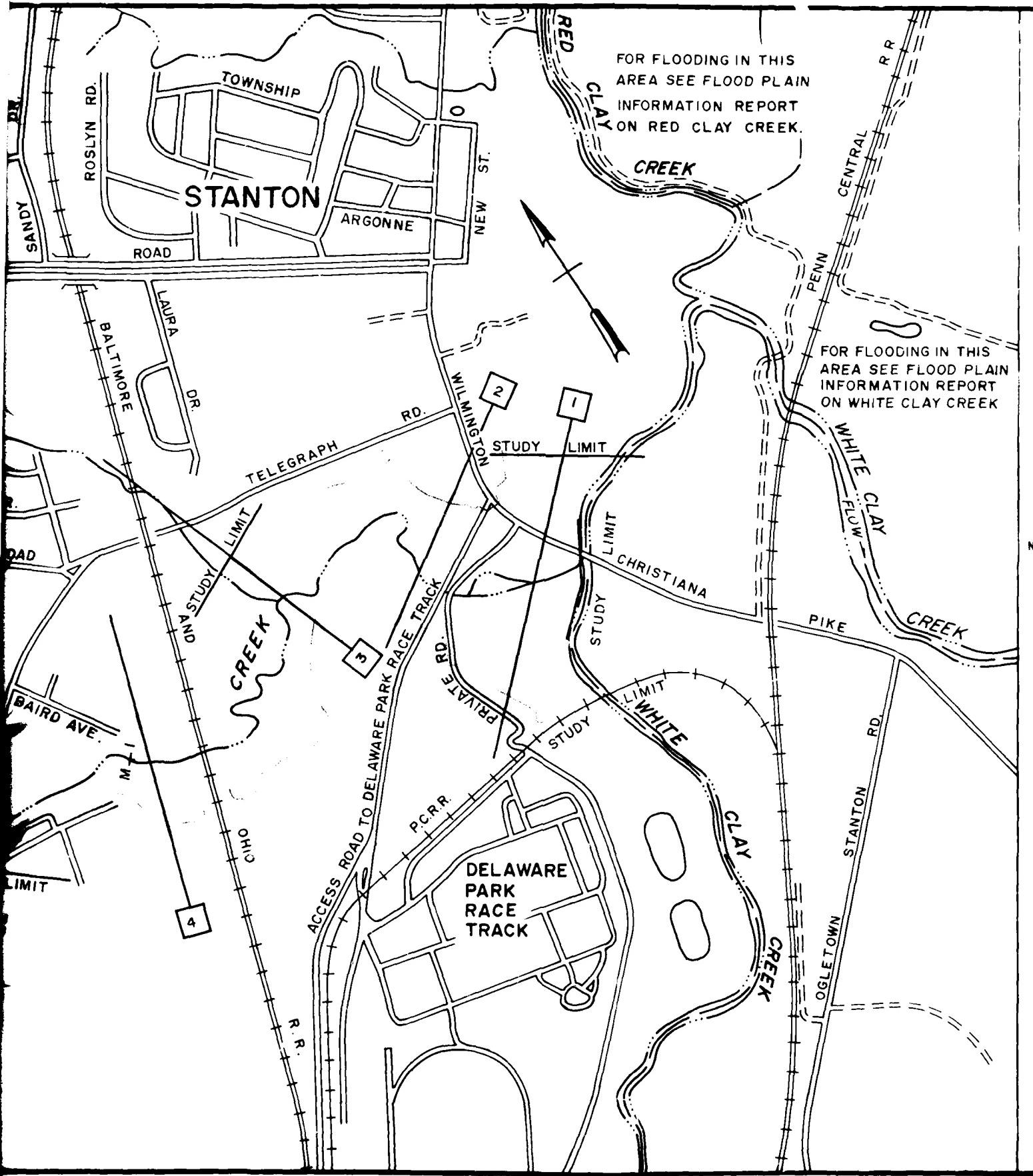


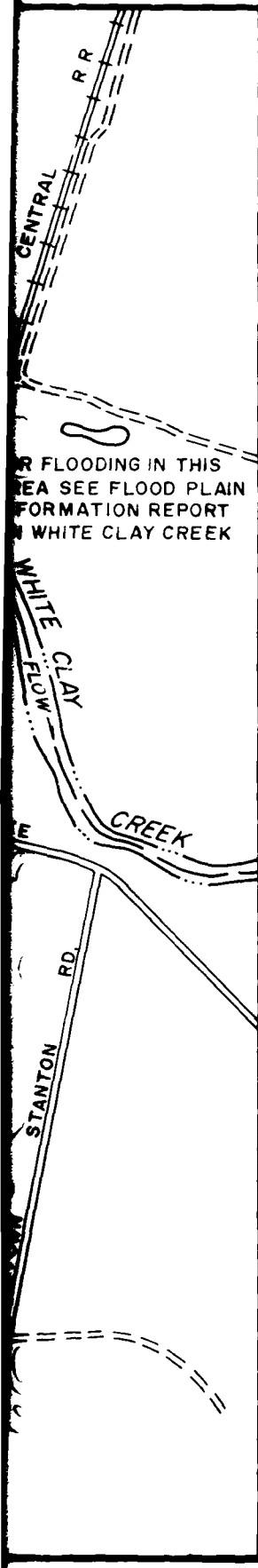
PLATE 5





NOTES

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LEGEND

OVERFLOW LIMITS

INTERMEDIATE REGIONAL FLOOD	STANDARD PROJECT FLOOD
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M+1 MILES ABOVE MOUTH

2 CROSS SECTION

GROUND ELEVATION IN FEET (U.S.C.
G.S. 1929 ADJ.) SEA LEVEL DATUM

7 STATE ROUTE

NOTES

1. MAP BASED ON U.S.G.S. 7.5 MIN. QUADRANGLE SHEETS: NEWARK EAST, DEL. 1953 & KENNEDY SQUARE, PA. 1968. MINOR ADDITIONS AND ADJUSTMENTS MADE BY CORPS OF ENGINEERS.
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT.
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4. MINIMUM CONTOUR INTERVAL IS 20 FT.

SCALE IN FEET

0 800 1600

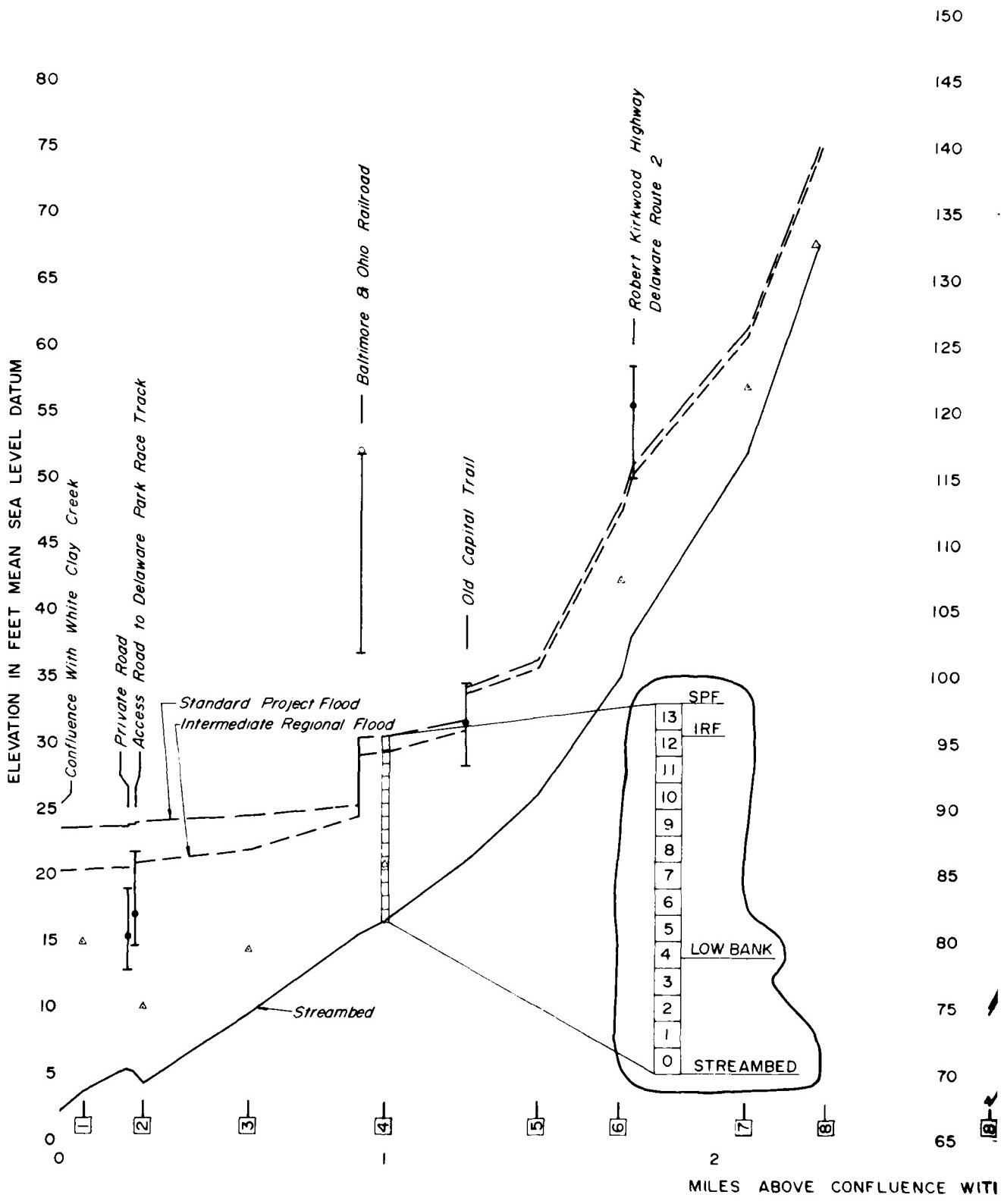
DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA

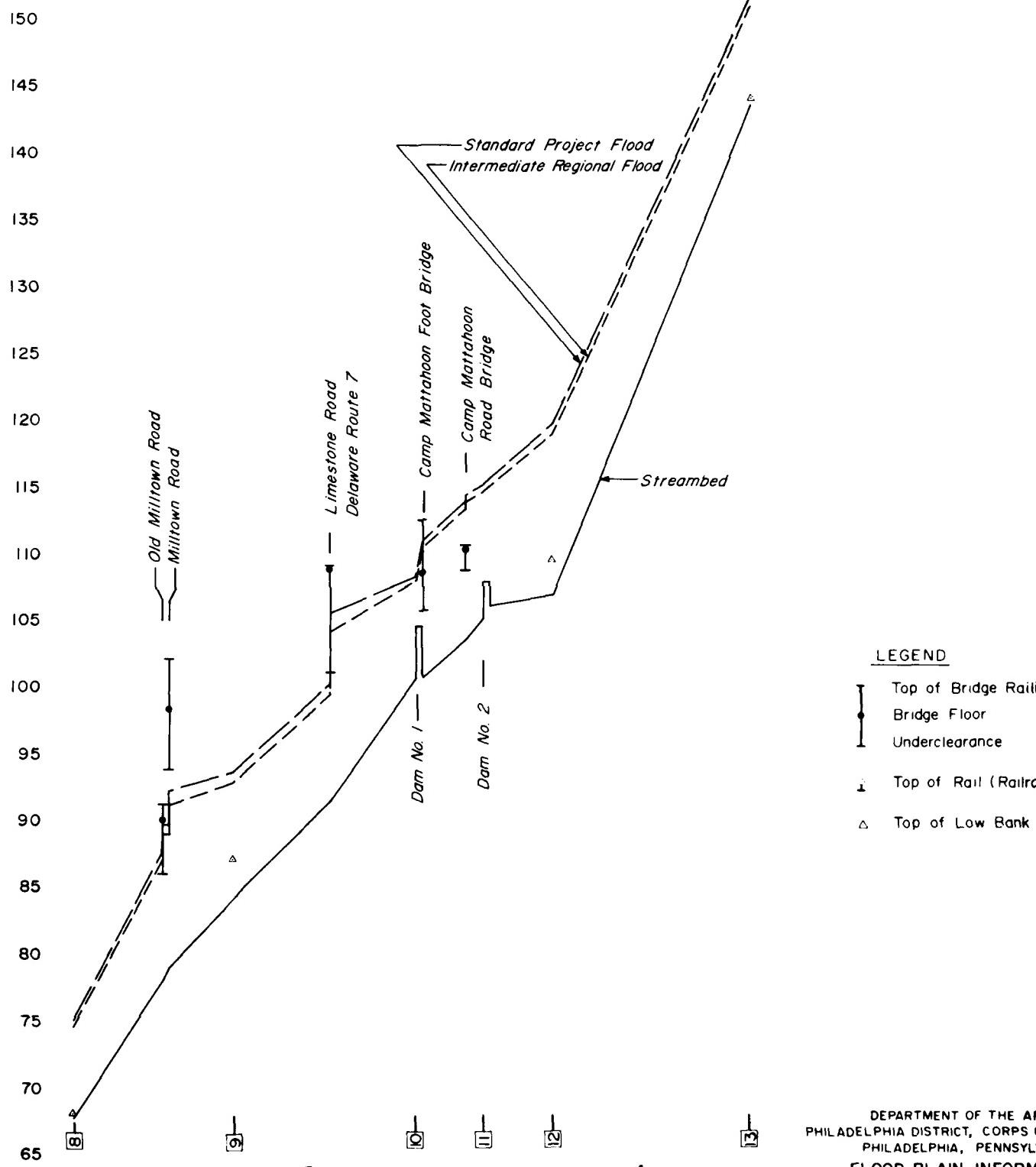
FLOOD PLAIN INFORMATION

MILL CREEK
NEW CASTLE COUNTY, DELAWARE

FLOODED AREAS

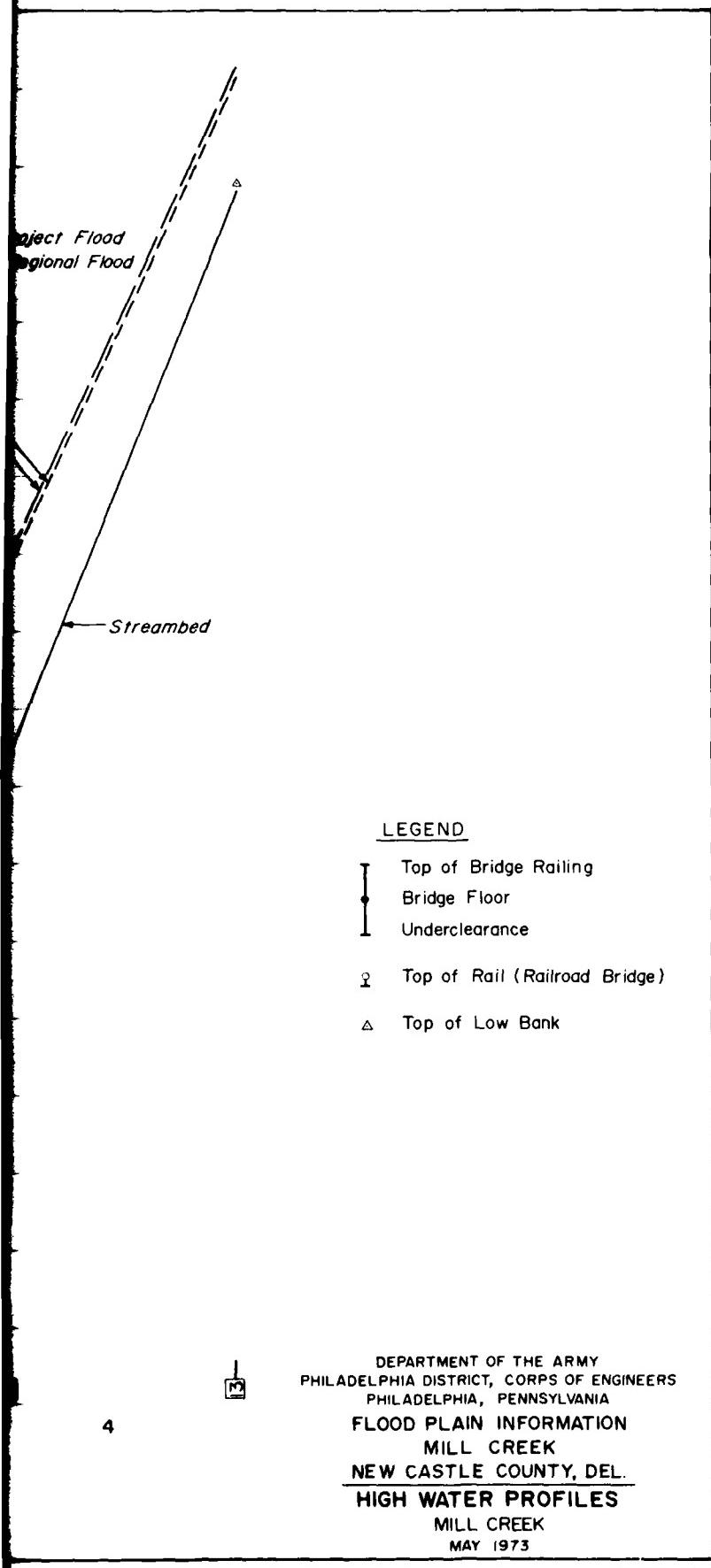
MAY 1973





ABOVE CONFLUENCE WITH WHITE CLAY CREEK

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PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
FLOOD PLAIN INFORMATION
MILL CREEK
NEW CASTLE COUNTY
HIGH WATER PROFILE
MILL CREEK
MAY 1973



DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA

FLOOD PLAIN INFORMATION

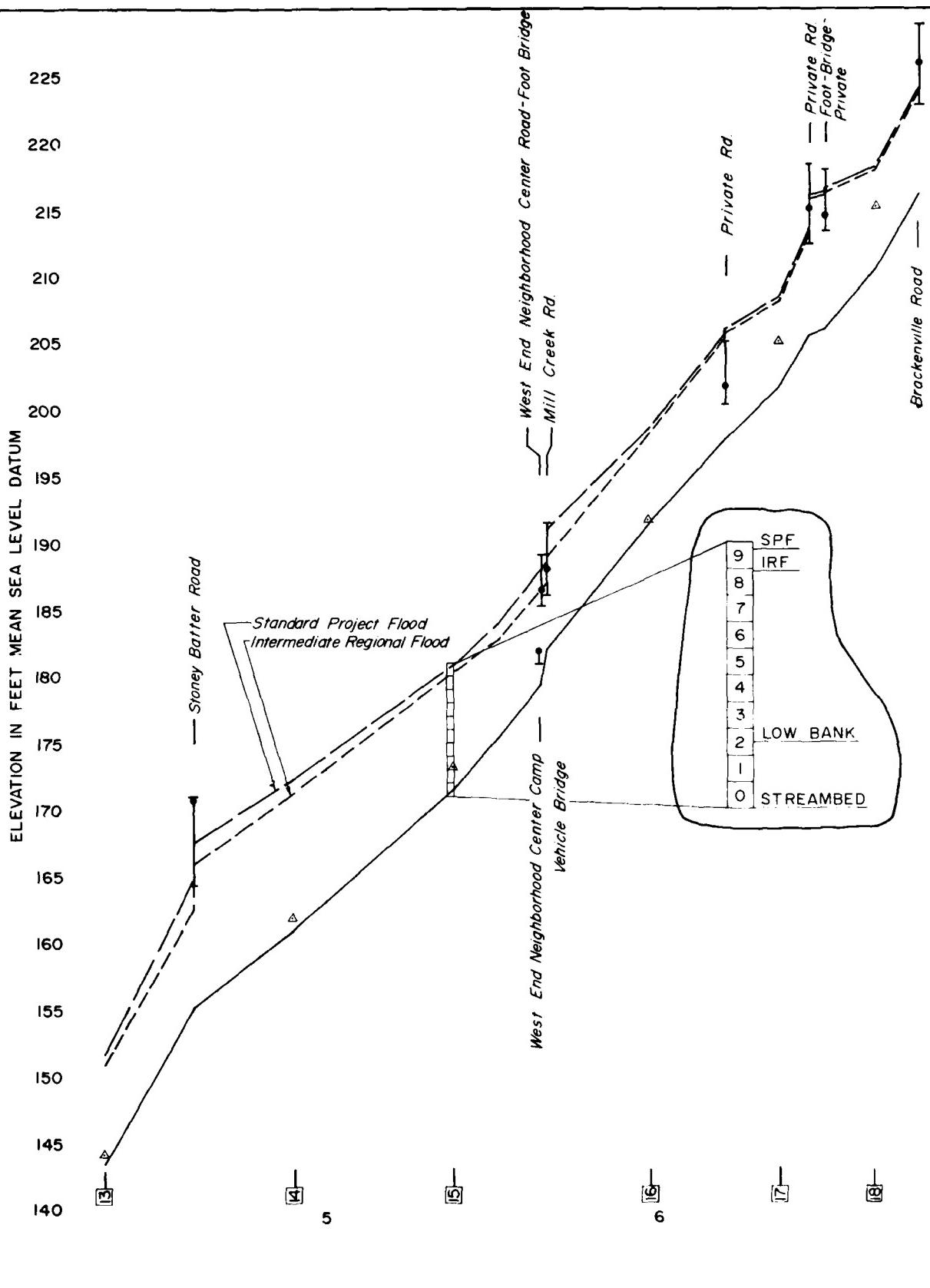
MILL CREEK

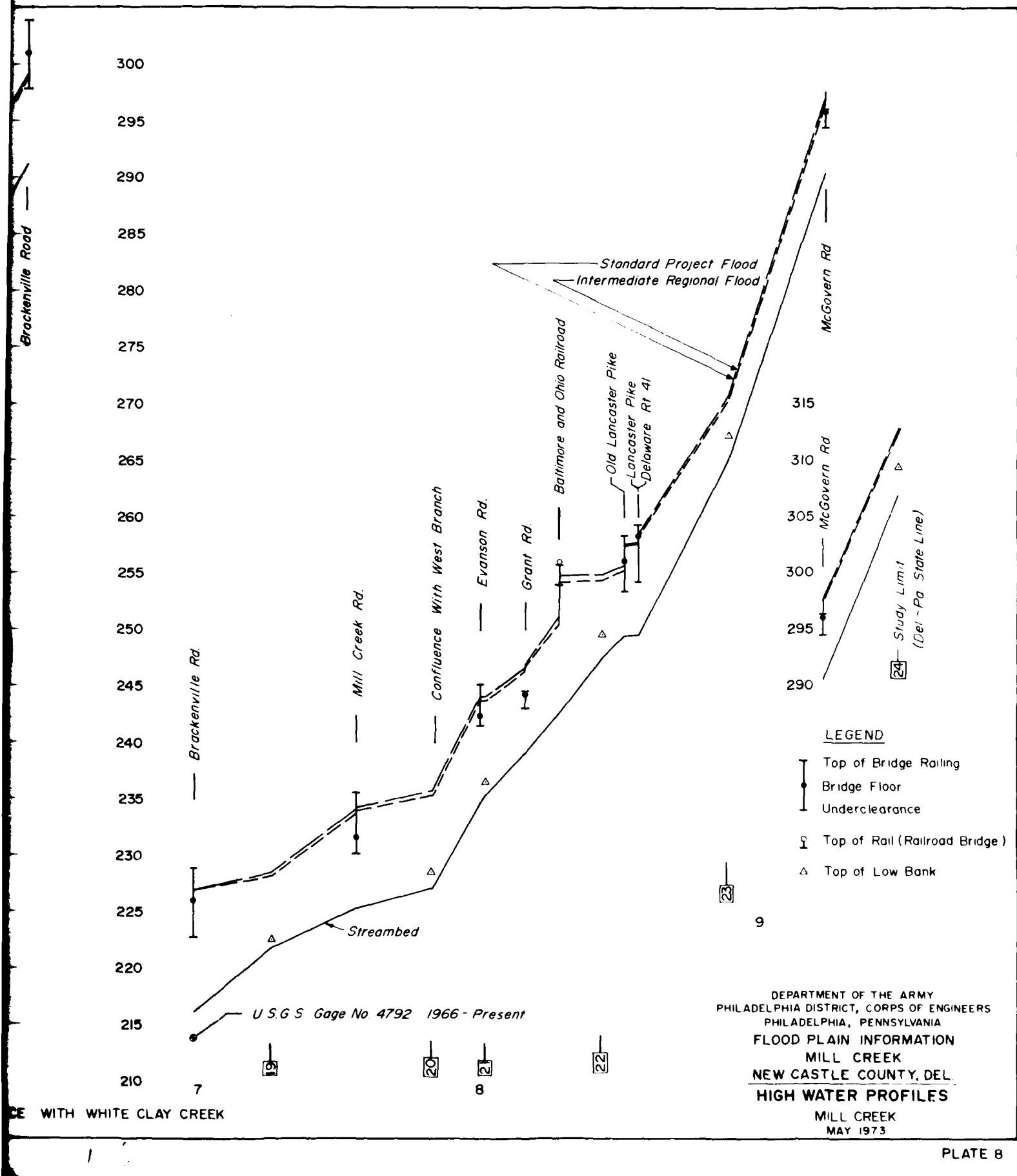
NEW CASTLE COUNTY, DEL.

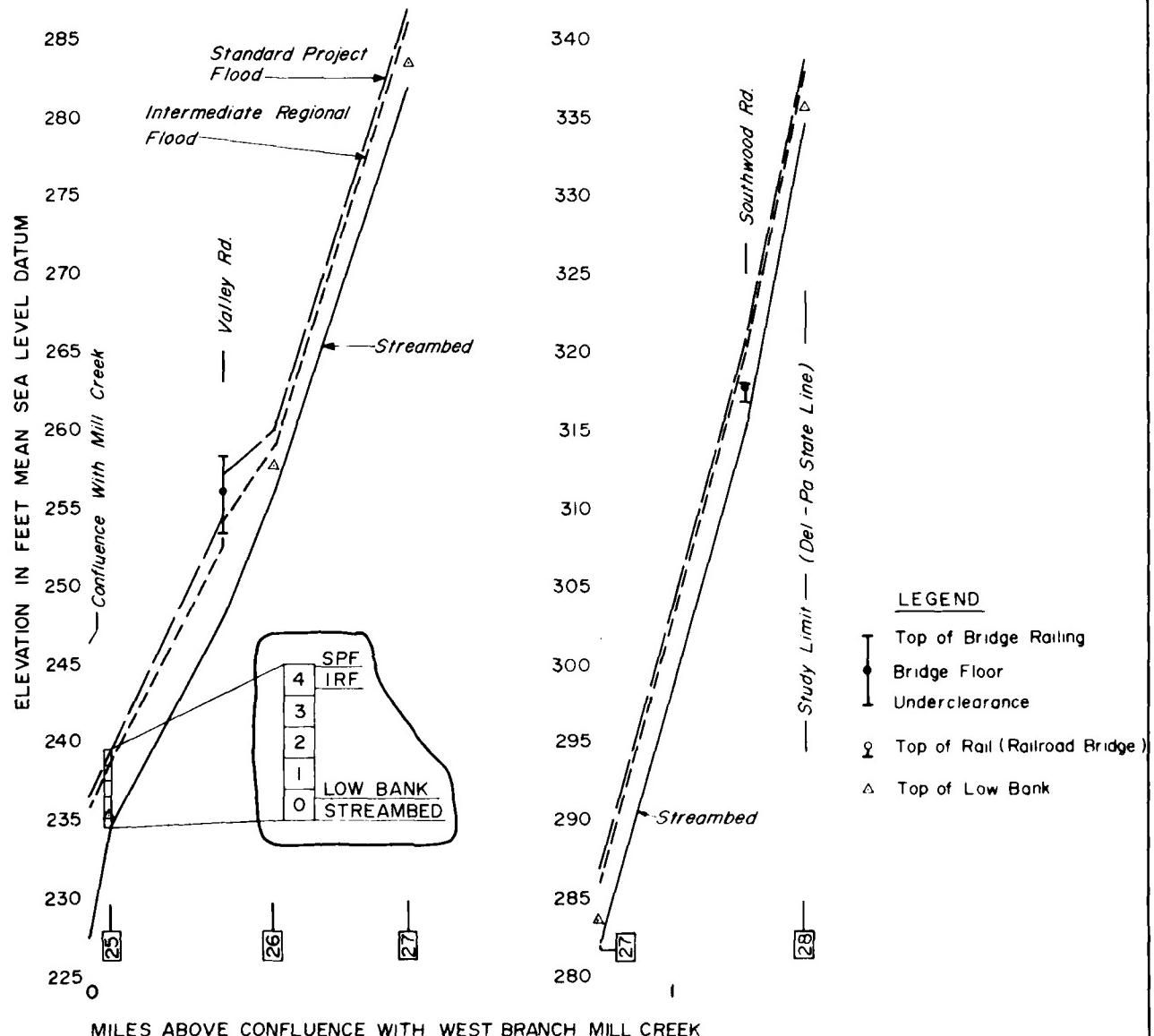
HIGH WATER PROFILES

MILL CREEK

MAY 1973



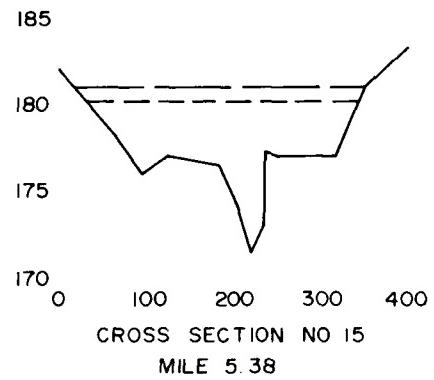
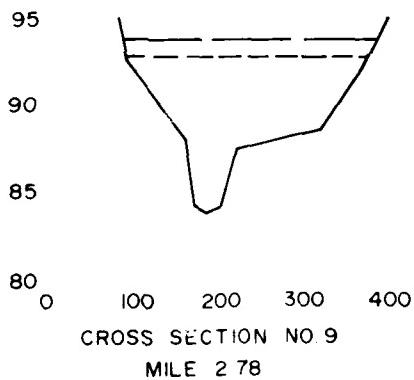
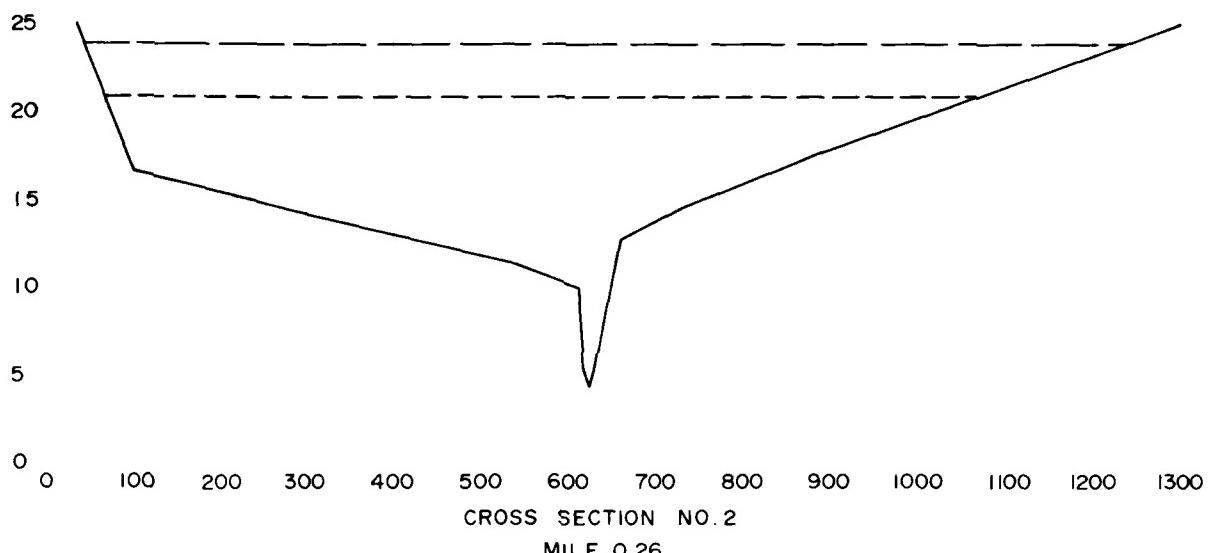




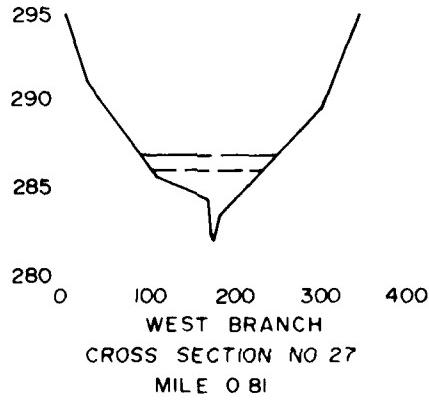
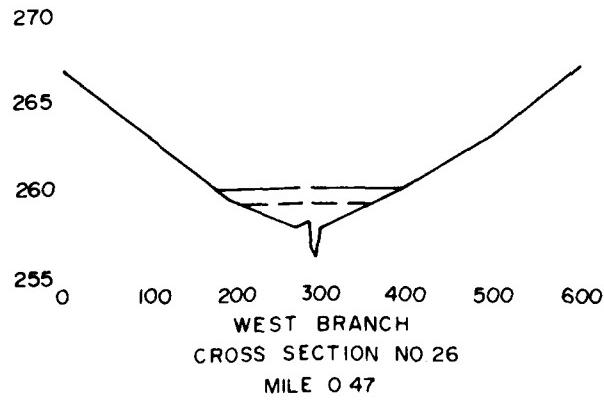
DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
FLOOD PLAIN INFORMATION
MILL CREEK
NEW CASTLE COUNTY, DEL.
HIGH WATER PROFILES
WEST BRANCH MILL CREEK

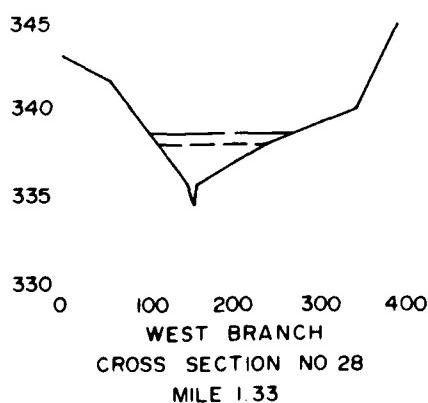
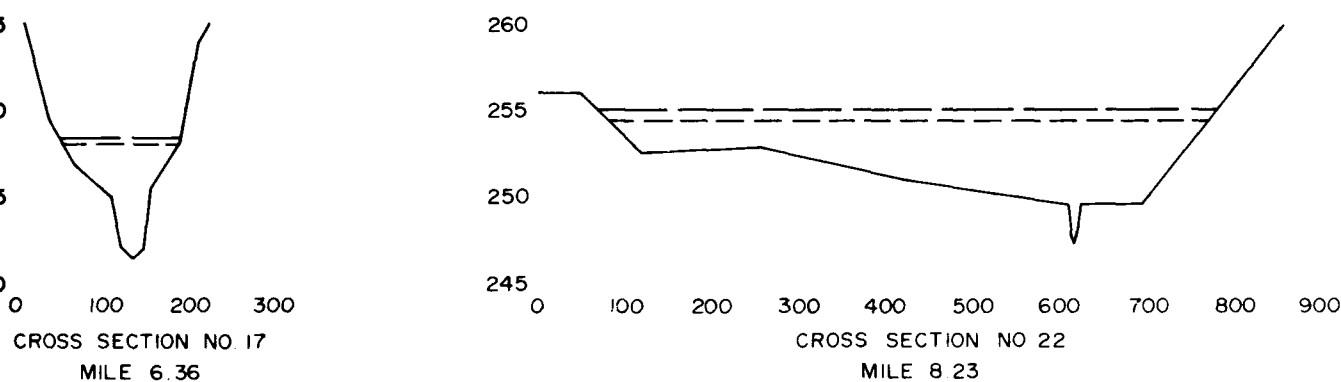
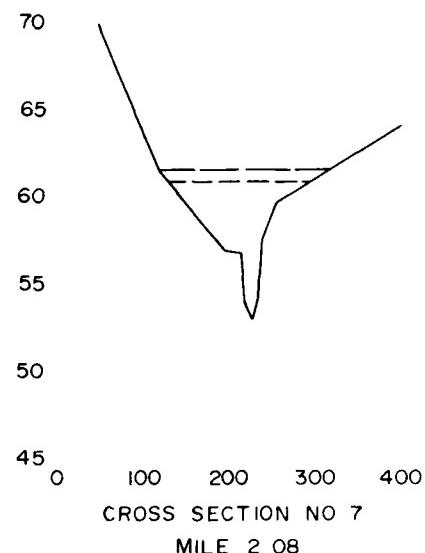
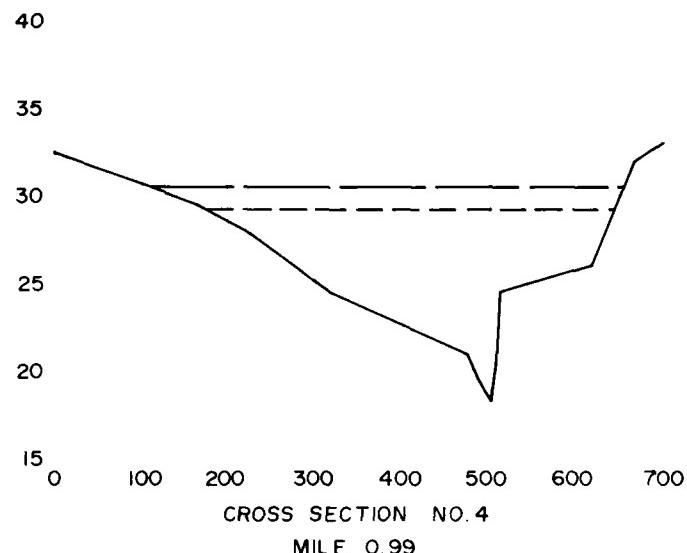
MAY 1973

ELEVATION IN FEET (SEA LEVEL DATUM)



CROSS S
MILE





NOTES:

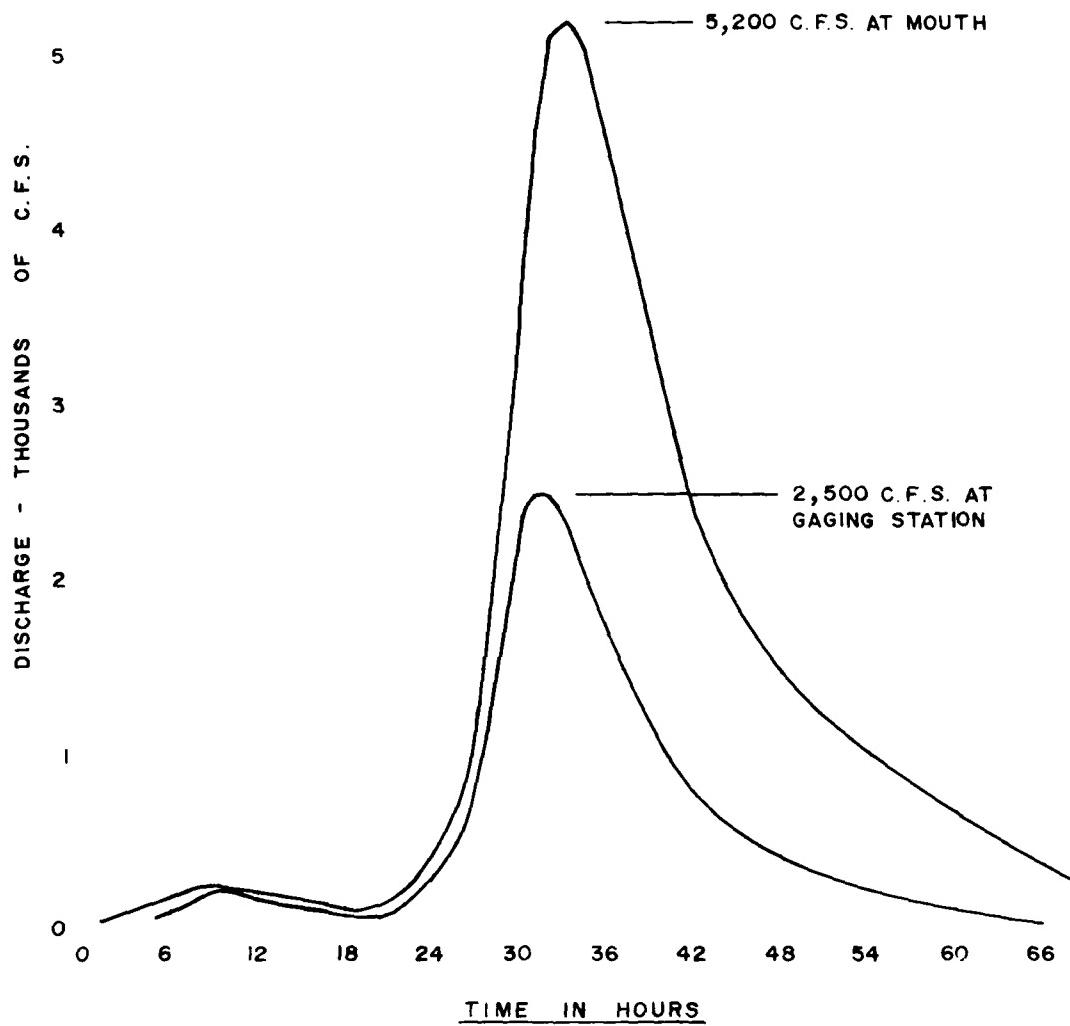
THE 18 SECTIONS ON MILL CREEK AND ITS WEST BRANCH NOT SHOWN IN THIS REPORT ARE ON FILE AT THE PHILADELPHIA DISTRICT, CORPS OF ENGINEERS AND ARE AVAILABLE FOR INSPECTION UPON REQUEST. CROSS SECTIONS TAKEN LOOKING DOWNSTREAM.

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA

FLOOD PLAIN INFORMATION
MILL CREEK
NEW CASTLE COUNTY, DEL.

SELECTED CROSS SECTIONS

MAY 1973



NOTES

<u>DRAINAGE AREA</u>	<u>SQ. MI.</u>
AT MOUTH	12.7
AT U.S.G.S. STREAM GAGING STATION AT BRACKENVILLE ROAD, HOCKESS, DELAWARE.	4.2

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STANDARD PROJECT FLOOD
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